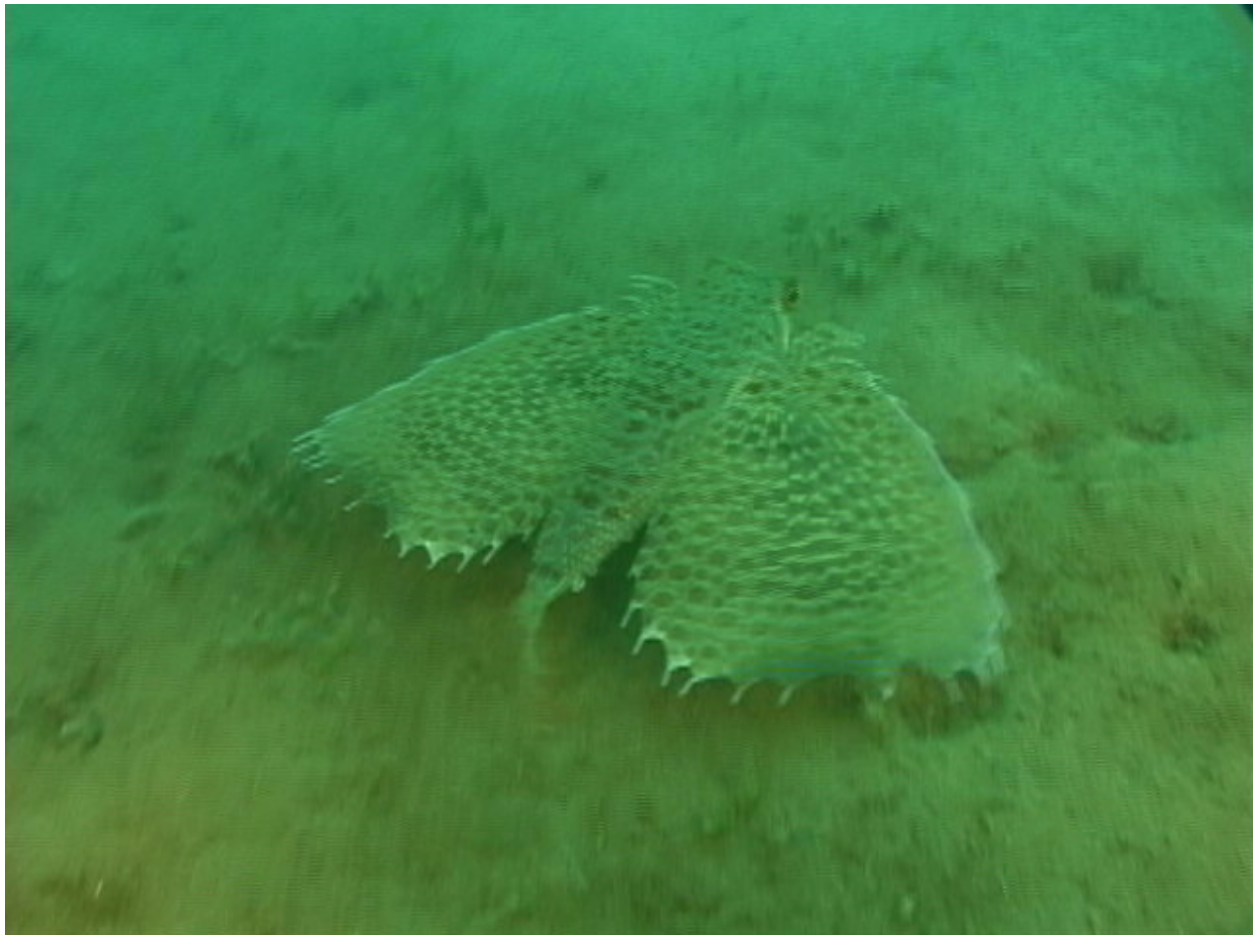




# Pathway Ranking for In-place Sediment Management (CU1209)

## Final Site II Report – Pearl Harbor

April 2006



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## **Performers:**

**SPAWAR Systems Center, San Diego**  
53475 Strothe Road  
San Diego CA 92152-6325

**Dr. Bart Chadwick\***

Phone: 619-553-5333  
Fax: 619-553-3097  
Chadwick@spawar.navy.mil

Ms. Vikki Kirtay  
Phone: 619-553-1395  
Fax: 619-553-8773  
Kirtay@spawar.navy.mil

**SEA Environmental Decisions**  
1 South Cottages, The Ford  
Little Hadham, Hertfordshire SG11 2AT,  
United Kingdom

**Dr. Sabine E. Apitz\***

Phone: +44 (0)1279 771890  
Fax: +44 (0)1279 771403  
drsea@cvrl.org

### **\*Principal Investigators**

**Germano & Associates**

Dr. Joe Germano  
Phone: (425) 653-2121  
Fax: (425) 562-6671  
germano@ix.netcom.com

**Virginia Institute of Marine Science**

Dr. Jerome Maa  
Phone: 804-684-7270  
Fax: 804-684-7250  
maa@VIMS.EDU

**Cornell Cooperative Extension**

Mr. Chris Smith/Mr. Ron Paulsen  
Phone: 631-727-3910  
Fax: 631-369-5944  
cfs3@cornell.edu

**Naval Research Laboratory**

Dr. Mike Montgomery  
Phone: 619-553-1395  
Fax: 619-553-8773  
mtm@ccsalph3.nrl.navy.mil

**Scripps Institution of Oceanography**

Dr. Wiebke Ziebis  
Phone: 858-534-1864  
Fax: 858-822-0562  
wziebis@coast.ucsd.edu

Dr. Joris Gieskes  
Phone: 858-534-4257  
Fax: 858-534-2997  
jgieskes@ucsd.edu

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## **1 Objective**

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The objective of this program was to provide an understanding of the relative importance of critical contaminant transport pathways in the risk, fate and management of near-shore, in-place contaminated sediments via: 1) An integrated suite of measurement techniques to characterize and quantify important transport pathways for in-place sediments, 2) A corresponding set of indices that quantify the transport phenomenon on a common dimensional scale and 3) Field scale evaluation of the effectiveness of the measurement tools and the importance of quantified transport pathways. This program consisted of two field demonstrations. The bulk of this report describes results of the second demonstration, which was carried out at Pearl Harbor, Hawaii.



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## **2 Background**

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Given the economic, logistical, technological and ecological limitations of contaminated sediment removal and treatment technologies, it is inevitable that some contaminated sediments will be left in place, in the short or the long term, even if contaminants pose some ecological or human health risk. However, leaving sediments in place has met with regulator and public resistance at many sites due to concerns about the long-term risk to the marine environment. It is assumed that the management process will seek to balance two parallel goals: 1) minimizing contaminant risk to the environment and human health and 2) minimizing cost (NRC, 1997). A set of diagnostic tools for characterizing and quantifying potential in-place contaminant pathways will allow for the selection, permitting and monitoring of in situ management strategies.

An appropriate evaluation of management choices involves a comparative evaluation of the potential effectiveness of removal-based management strategies vs. appropriate in-place management strategies. This requires knowledge of the relative importance and magnitude of potential pathways of contaminant removal or transport in sediments and the surrounding environment. Determining the relative importance of these mechanisms on a site-specific basis is critically important to the selection, approval and success of any in situ management strategy. Adequate approaches for evaluating these pathways do not currently exist. Assessment and monitoring strategies for multiple contaminant pathways before, during and after in-place remediation must be standardized and validated.

While EPA and the Army Corps of Engineers have developed extensive data and guidance documents on the evaluation of contaminant pathways in sediment management (see <http://www.wes.army.mil/el/dots/> for extensive resources), the focus and driver have been the disposal of dredged materials (Lunz, et al., 1984; Fredette and Nelson 1990; Fredette et al., 1990; Sumeri et al., 1991; Fredette et al., 1992; Murray et al., 1994; Palermo et al., 1998, USEPA, 1992). By necessity, dredged material will be removed (and exposed at least in part to the water column) and thus pathways of contaminant transport such as leaching, bulk resuspension and amenability to ocean disposal have been extensively studied.

On the other hand, many of the contaminated marine sediment sites are currently under investigation due to ecological concerns, not for construction or navigational dredging. Many of these sites are in shallow, coastal areas, and thus are much more likely than offshore (disposed) sediments to be impacted by resuspension by ship and storm activity, as well as advective processes such as groundwater flow, tidal and wave pumping. While these processes are recognized in the oceanographic community as having significance to the transport of chemical constituents (see Moore, 1999 and references therein), the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined in contaminated sediment sites. Fundamentally different management and monitoring strategies must be applied for these different processes.

In this discussion, we define the range of in situ sediment management options as a continuum – beginning with those requiring no containment or physical control (those which are to allow natural attenuation or biodegradation or more engineered in-place treatments), through simple or thin caps, and ending with more aggressive capping and containment technologies using armor, geofabric, or other sediment or contaminant controls. In essence, in-place sediment management consists of “pathway interdiction” while ex situ approaches represent mass removal. If contaminants are to be left in place, it is critical to evaluate potential pathways by which

contaminants might pose an ecological or human health risk, and to monitor, minimize or eliminate these pathways. As Dennis Timberlake, Program Manager for Contaminated Sediment Risk Management Research at the EPA's National Risk Management Research Laboratory states, "Currently, there is no demonstrated, systematic process for measuring and evaluating contaminant transport pathways within sediment systems." This project seeks to address that situation.

### **3 Technical Approach**

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### 3.1 CONVERTING FIELD MEASUREMENTS INTO EQUATION TERMS: APPROACHES, ASSUMPTIONS AND LIMITATIONS

Processes controlling the fate of contaminants in sediment can be broadly categorized into those governed by porewater dynamics, and those governed by solid phase dynamics. The porewater and solid phase compartments and similarly linked by a range of biogeochemical processes (Figure 3-1).

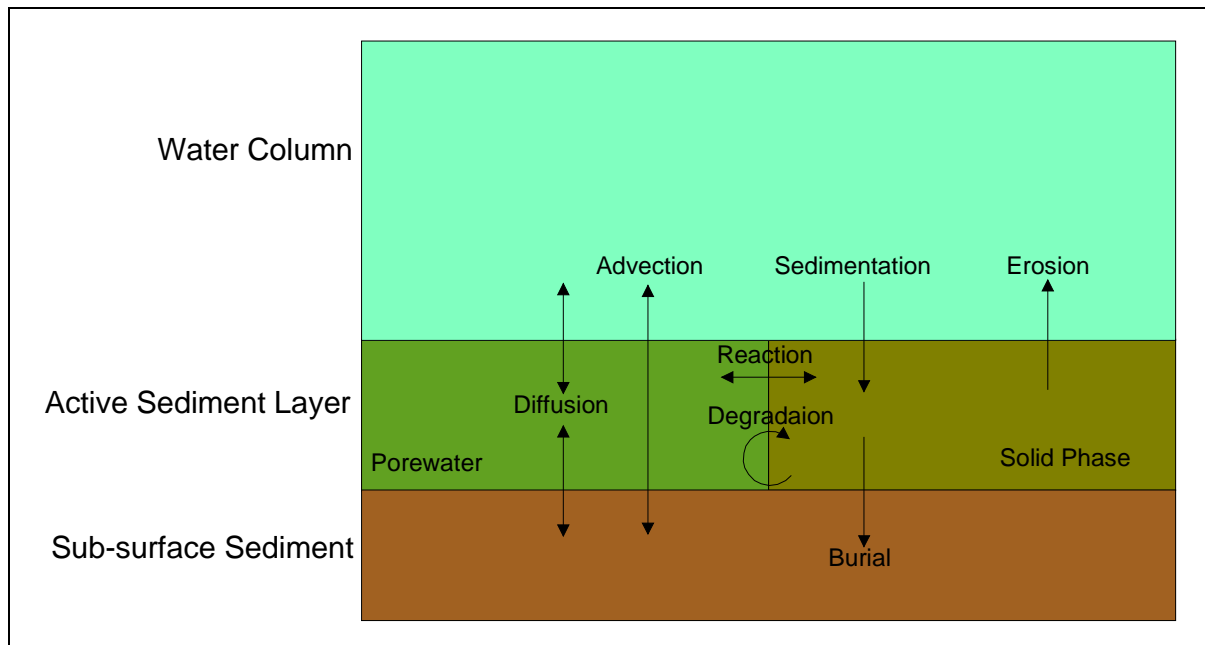


Figure 3-1. Pathway schematic for contaminant transport mechanisms in sediment.

Contaminant migration in porewater can be described from basic principles by the one-dimensional vertical chemodynamic balance,

$$\frac{dc}{dt} = \frac{d}{dz} \left( D \frac{dc}{dz} \right) - w \frac{dc}{dz} - R \quad (1)$$

where  $c$  is the concentration,  $z$  is the depth,  $D$  is the effective diffusivity (including chemically and biologically driven diffusion),  $w$  is the vertical pore fluid velocity and  $R$  is a chemical reaction term, which includes degradation, and transformations between porewater and solid phase.

In words, this equation states that the time change in concentration in the porewater for a given constituent will be controlled by the relative balance of diffusion, advection across the interface, and chemical reactions within the sediment.

Given the objective of this program to provide an understanding of the relative importance of critical contaminant transport pathways, we have attempted to develop “field-measurable” parameters that, as much as possible, parallel the processes addressed in most risk and recovery



models. In order to produce a useful form of Equation 1 for interpreting our field measurements, we must convert many of the above parameters to field-measurable terms. Flux of contaminants by various pathways can then be integrated over a vertical control volume of depth  $H$ , where  $H$  is chosen to be a representative depth over which we wish to evaluate the changes in chemical concentration and mass balance. The discussion below will first discuss the basis of some of these terms, then how they will be integrated in a modified version of Equation 1, and then how the instruments themselves are used in support of this effort.

## **Depth Scale**

If integrated measures of multiple pathways are to assess contaminant transport through sediments, a common area, thickness and thus volume of sediment must be specified. A difficult issue in any integrated field effort is the problem of scaling. While we are attempting to put a number of disparate processes into common terms (as do most models), these processes occur at very different rates, and on different scales. Furthermore, measurement techniques examine the processes at different rates and scales. For instance, the microprofilers measure porewater chemistry at mm resolution, while the BFS and seep meters enclose a few square feet of sediment. The BFS is deployed for a few days while the microprofiler takes minutes. Biodegradability, permeability, contaminant levels, flow, etc., vary spatially and as a function of tidal cycle, temperature, etc. Thus, whether in a model or a field effort, several simplifying assumptions are made. A difficult question the PRISM team evaluated was choice of sediment depth of interest, or  $H$ , for the integrated equations. Clearly, the depth of interest can be based upon some management goal, chemical, physical or biological parameter (e.g., depth of contaminated layer, depth considered to be at risk in an extreme storm, depth to be dredged, stratigraphic layer depth, depth of tidal penetration, bioturbation depth, aerobic depth, mixed layer etc.). During the field design effort, it was decided that the Sediment Profile Imaging (SPI) camera would initially be used as a reconnaissance tool to select the deployment sites. Then, for a field determination of  $H$ , which would guide sampling decisions such as core depths to be analyzed, etc., SPI images were used to designate  $H$ , based on the depth to which the sediment column was bioturbated, determined by the depth of deepest feeding void. Once the image analysis data are completed, we can examine which measurement is the best, based upon correlations with the other data, (i.e., the depth of the mean apparent Redox Potential Discontinuity (RPD), the maximum RPD depth, the minimum feeding void depth, the maximum feeding void depth (which was the one used for the "quick-look" estimate), or the average feeding void depth), for future deployments. Thus, based upon field SPI imaging, core depths, etc., were designated for other measurements.

## **Diffusive Fluxes**

An important pathway of contaminant transport for in situ sediments, and one that has been the most studied and modeled in support of in place capping of sediments, is the diffusive transport of contaminants across the sediment/seawater interface. The Benthic Flux Sampling Device (BFS, see sections below for details) is designed to measure diffusive fluxes of contaminants of potential concern (COPCs) across the sediment/seawater interface. To do this, a volume of water is enclosed in a non-reactive "box", which is sealed with a knife-edge at the sediment-seawater interface. Water samples are taken over time. When returned to the laboratory, concentrations

of chemicals of interest are measured in water samples. If COPCs are either fluxing into or out of the sediment, these concentrations will change over time. Because the volume of water and sediment surface area are known, these results can be converted to a flux (such as mg/m<sup>2</sup> day).

The BFSDD as used in standard applications cannot separate fluxes driven by diffusion from fluxes across the sediment-water interface driven by bioirrigation. In general, such fluxes, which are inferred by measuring the changes in COPC concentrations in the sealed chamber over time, can result from multiple mechanisms, such as diffusion from porewaters, partitioning from sediments and bioirrigation. However, previous studies by us and other investigators (e.g. Dryssen et al., 1984) suggest that, when oxygen is allowed to deplete in a BFSDD chamber, the flux rate of Si drops significantly. In applications designed to measure metal flux, oxygen levels are kept constant in the BFSDD so metal redox states (and thus solubilities) stay constant. Si, on the other hand, is not sensitive to redox state, and thus oxygen does not have to be maintained to maintain its solubility. Thus, a reduction in Si flux corresponding to an oxygen drop is not the direct result of a change in redox states, suggesting that flux from sediments to the chamber from biological irrigation had ceased or significantly decreased due to oxygen limitations for bioirrigating organisms. It is this phenomenon that is being exploited to separate “diffusive” from “bioirrigation” flux in the field.

To separate flux by these two mechanisms, “normal” and “bioinhibited” flux were measured in the BFSDD, by first maintaining oxygen levels and then turning off the oxygen source and allowing respiration to deplete the oxygen. The difference in the flux with and without oxygen was then designated as the flux that was driven by bioirrigation. Thus, if one considers the aerobic and anaerobic runs separately, during the aerobic (standard) run, COPC fluxes can be considered to be the sum of diffusive and bioirrigation fluxes, which will be termed  $F_{COPC-DT}$ . Under anaerobic conditions, flux by bioirrigation is inhibited, so fluxes measured are assumed to be “purely” diffusive. However, since the redox state of the overlying water has been changed, these activities may change the diffusive properties of metals and/or organics. Thus, Si was used as a surrogate for COPC flux - Si was measured, and then COPC fluxes were calculated based upon the surrogate:COPC ratio in the biologically active flux measurements. We assume that both Si and the COPC will both diffuse and be transported by bioirrigation at a constant ratio. For a given COPC, then, the bioinhibited flux (assumed to be diffusive) will be calculated as

$$F_{COPC-Diff} = F_{Si-Diff} * (F_{COPC-DT}/F_{Si-DT}) \quad (2)$$

Finally, then, the flux of COPC as a function of bioirrigation ( $F_{COPC-DB}$ ) can be calculated by subtraction:

$$F_{COPC-DB} = F_{COPC-DT} - F_{COPC-Diff} \quad (3)$$

The SPI camera is used as a qualitative “reality check” for this measurement. If a very high bioirrigation flux is calculated, then SPI images of the sediments will be examined for evidence of bioirrigating organisms. Over time (but not with just two field sites), it may be possible to use SPI images as predictors of the ratio of diffusive and bioirrigation flux.

## Advective Fluxes

Advection of contaminants through sediments and into the overlying waters is generally considered in capping models only in terms of the advective flow during consolidation. However, since many of these sites are in shallow, coastal areas, and thus are much more likely than offshore (disposed) sediments to be impacted by advective processes such as groundwater flow, tidal and wave pumping, the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation should be determined in contaminated sediment sites. In field measurement terms, the advection rate ( $w$ ) expressed in cm/day (average) and can be applied to metals, PAHs and nutrients. As with the BFS, a seep meter encloses a volume of water at the sediment/seawater interface. However, while the BFS is a nearly closed system, the seep meter allows for advective flow. Using an ultrasonic flow meter, flow volume can be measured. With a known surface area of sediment, fluid flow rates ( $w$ ) can thus be calculated. Particularly in nearshore sediments where tidal cycles can have a strong influence, fluid flow rates vary, in magnitude and direction, over time. There are then several options for the choice of  $w$  to insert into the flux equations. One option is to run the equations with  $w$  from various parts of the tidal cycle – generating maxima and minima, or flux ranges. Another is to use net flow over a selected time period. Depending upon the questions being asked at a site, there may be more than one appropriate choice.

To convert this flow into a chemical flux, it is necessary to know the COPC concentrations in the fluid flow. This can be done two ways. In one, some of the fluid that flows through the seep meter is collected, and concentrations are measured in the laboratory. In the second, COPC concentrations in porewaters in the mixed layer ( $c_H$ ), the deep layer ( $c_{H-}$ ), and at the surface are measured ( $c_0$ ). Depending upon the analyte of concern, this can be done either with microprofilers, or with porewaters collected and brought to the laboratory. In the case of the Pearl Harbor site, cores were collected as closely as possible to where seep was measured. Cores were cut at depth  $H$  determined by field SPI imaging and the porewaters were collected from the composited core from the surface to depth  $H$ , and from  $H$  to the bottom of the core. In addition, at some station the new seep meter which can both ultrasonically measure flow and collect water samples during a positive flow event was used.

## Biodegradation Rate

Any chemical or biological process that removes contaminants from the sediment can be considered a reaction flux. In this study, the only reaction term considered is biodegradation. As with all other parameters, the only organic component evaluated was PAHs. While there may be other organic contaminants of interest (both degradable and recalcitrant), they were outside the scope of this study. PAH mineralization rates can be expressed in units of  $\mu\text{g PAH Carbon metabolized per g of sediment dry weight per day}$ . In this study, a field measure of instantaneous PAH mineralization was used to determine this parameter. To estimate how much degradation is occurring over the study site, the averages for sections of core slices can be integrated with depth (up to the 15 cm studied). In the Site I demonstration, mineralization rates for unbioturbated and bioturbated depth sections were determined. Ultimately, it is hoped that SPI reconnaissance images can be used to determine the bioturbation depth for a given station or area, and then a depth-integrated PAH mineralization rate can be determined. A patchwork of these estimates can be used to estimate biodegradation within the entire study site. Environmental parameters

affecting PAH metabolism may be inferred from comparison with the nutrient, electron acceptor, ambient PAH, and metal concentration in core slices taken for measurement by SIO team members. If groundwater transport of PAHs is measurable, whether this transport mechanism for PAHs is offset by intrinsic biodegradation can be calculated using a direct depth-integrated rate comparison. In addition, if the deposition rate of PAHs to the sediment on a per surface area basis is greater than the biodegradation rate estimates for the same area; one would expect an accumulation of PAHs in the surface sediments. The ratio of PAH to non-PAH organic matter between the sediment trap material and the surface sediments can be reconciled by comparing PAH mineralization in surface sediments to bacterial production (metabolism of all organic matter).

A few important points must be made about the biodegradation rate portion of this study. Firstly, only PAHs are being examined, though other organic COPCs may be undergoing intrinsic recovery. Any potential reactions affecting inorganic COPCs were not considered either. Secondly, this assay focuses on aerobic mineralization processes, and may thus underestimate potential downcore mineralization. It has been shown by a number of workers that degradation of some PAHs does occur in this region by strictly anaerobic processes. Thirdly, total PAH mineralization rates are being extrapolated based upon spiked measurements of three individual PAHs. While the mineralization rates of these three PAHs have been observed to be strikingly similar at many sediment sites (by this methodology), the simplifying assumption that these spiked PAHs will reflect the behavior of the full PAH mixture is still subject to some controversy. To be conservative, parallel calculations will be made for just the PAHs measured as well as for total PAHs.

## Resuspension

Contaminants can flux out of a sediment layer due to erosion if they are resuspended and transported from the site. This assumes not only a resuspension event but also a situation in which contaminated sediments do not simply re-settle. A more complex situation can occur as well, in which resuspended sediments re-equilibrate with overlying waters, releasing some contaminants, and then resettling with lower contaminant levels. In this study, it is assumed that sediments that resuspend will be transported from the site and will not redeposit. However, it is also assumed that redeposition will be captured in the settling traps, and thus any over-estimate of erosive removal will be offset by this measurement. Flux of a given contaminant by erosion is calculated by the equation:

$$F_E = Ec_S = K_E(\tau - \tau_c)c_B \quad (4)$$

$K_E$ , and  $\tau_c$  are determined using the in situ flume.  $\tau$ , the shear stress, varies over time. For use in Equation 10, it can be based upon an average shear stress, a maximum shear stress (perhaps based upon an extreme event or a ship passing), or a range of expected stresses. Using Acoustic Doppler Current Profiler (ADCP) deployments, current velocities were measured for two months, indicating the shear stresses that can be expected through normal tidal cycles, and also capturing a few events that are interpreted as the effects of ships passing overhead. Historical records of storm events, and standard models can predict the effects of extreme events, but these data were not available for Pearl Harbor sites. The flume measures the critical shear stress, as well as erosion rates under various shear stresses.

The COPC concentration in suspended sediments ( $c_s$ ), was ultimately based upon COPC concentrations in bulk surface sediments, composited sediments, and filter samples.

## Sedimentation

If flux of contaminants is modeled or measured in a constant thickness of sediments, contaminants can flux into a layer of sediment if sediments with COPC levels higher than those in the layer are deposited, but can flux out of the layer if cleaner sediments are deposited. Sedimentation rates were determined by two methods: sediment traps and radioisotope dating of cores. These two approaches give insight into sedimentation at very different timescales, and the results, their similarities, differences, and implications, are discussed further in the results section.  $C_B$  is determined in the laboratory – it is the COPC concentration of bulk sediments at the site.  $C_S$  is based upon COPC concentrations found in traps. As will be discussed below, this equation will be modified based upon field observations.

### 3.2 TRANSPORT EQUATIONS FOR PRISM ASSESSMENT

The PRISM measurement framework is tied to a classical 1-dimensional vertical mass balance model of contaminated sediments. Mobility is quantified as a net flux from the “active” surface layer, and changes in this layer result from the balance of fluxes through the defined pathways of mobility. For the PRISM program, these theoretical equations are modified so that field-measurable parameters can be used. As stated before, contaminant migration in porewater can be described from basic principles by the one-dimensional vertical chemodynamic balance shown in Equation 1. Equation 1 can be rewritten as

$$\frac{dm}{dt} = D \frac{dc}{dz} \Big|_0^H - wc \Big|_0^H - RH \quad (5)$$

where  $m$  is the mass per unit area. The diffusion term on the right can be separated into biological and chemical components and simplified assuming that the diffusion through the bottom of the control volume (at  $z=H$ ) is negligible. However, for the advective flux term it is unlikely that the chemical transport into the bottom of the control volume is small compared to that exiting at the top, thus both terms must be retained. Finally, the reaction term can be separated into separate terms for degradation (loss) and interaction with the solid phase. Equation 5 then becomes

$$\frac{dm}{dt} = (D_C + D_B) \frac{dc}{dz} \Big|_0^H - wc \Big|_0^H - R_B H - R_S H \quad (6)$$

where  $D_C$  is the chemical diffusion constant,  $D_B$  is the bioirrigation diffusion constant,  $R_B$  is the biodegradation term, and  $R_S$  is the solid phase reaction term. The first term on the right hand side represents the diffusive flux at the sediment-water interface, precisely what is measured using the Benthic Flux Sampling Device (BFSD). The standard BFSD protocol does not distinguish

between chemically and biologically mediated fluxes, however, utilizing the bioinhibited BFSD protocol should allow the chemical flux component to be isolated and then the biological contribution to the flux can be estimated by difference. The second term on the right is the differential advective flux at the sediment-water interface and bottom of the control volume. The sediment-water interface term can be quantified directly by use of the Tidal Seepage Meter or by determining the flow with the TSM and the concentration by direct measurement of the porewater. The advective term at the bottom of the control volume can only be determined by measuring the flow with the TSM, and collecting porewater at depth H to determine the concentration. If most of the contaminants are confined to the upper level between  $z=0$  and  $z=H$ , then the second term may be negligible. Quantification of the degradation term can be achieved by direct measurement of  $^{14}\text{C}$  labeled compound mineralization rates. The solid phase reaction term can be evaluated from two primary perspectives. In the case of the typical historically contaminated site, the solid phase sediment is generally viewed as a source of contaminated material to the porewater. In this case, the reaction term can be viewed as a steady source term that is balanced (at least over short time scales) by the losses due to diffusion, advection and degradation (i.e.  $dc/dt = 0$ ). In the other common case where a contaminated groundwater plume is migrating through the sediment, the solid phase may act as a sorptive sink for the contaminants. In this case, the source of the contamination is likely to be advection through the bottom of the control volume, which will in turn be balanced by interfacial losses and degradation. Thus depending on the site and the contaminant characteristics,  $R_s$  may act as either a source or sink, however if we assume that steady state conditions prevail, then it will simply be the balancing term and need not be directly quantified.

In a similar way, the solid phase dynamical balance is governed primarily by the balance between deposition and erosion. If erosion exceeds deposition, the sedimentation rate is negative, and contaminated sediment may be removed from the site via this process. On the other hand, if deposition exceeds erosion, then the sedimentation rate will be positive and the site will accumulate new material. If this material is relatively clean, then this sedimentation may result in a perceived “loss” of contaminated material from a given control volume, since the more contaminated material will be buried, and thus effectively moved through the bottom of the control volume at depth H beneath the sediment-water interface. Indices for solid phase transport phenomenon can be characterized in a similar way as those for porewater dynamics. The erosion rate of a sediment (mass per unit area) can be parameterized as

$$E = K_E (\tau - \tau_c) \quad (7)$$

where  $\tau$  is the bed shear stress,  $\tau_c$  is the critical shear stress for erosion, and  $K_E$  is a bed dependent erosion rate constant. Given the solid phase sediment contamination concentration, the mass flux of contamination per unit area due to erosion can be calculated as

$$F_E = Ec_s = K_E (\tau - \tau_c) c_B \quad (8)$$

where  $c_s$  is the solid phase concentration. Here the site-specific bed parameters  $K_E$  and  $\tau_c$  can be determined directly from the in situ flume measurements, and the sediment concentration from traditional solid phase chemistry.

In the case of sedimentation of clean material into the layer of depth H we can assume that contaminated material is displaced through the bottom of the control volume as clean material is added at the top and parameterize the flux as

$$F_S = S(c_B - c_S) \quad (9)$$

where S is the sedimentation rate in mass per unit area, and  $c_S$  is the solid phase concentration of the material that is settling onto the bed. The sedimentation rate can be estimated from either age-dated cores, or from sediment traps.

Taking the most common case for a historically contaminated site, assuming steady state, and redefining terms based on measured parameters, equation 3 can be rewritten as follows

$$\sum flux = -R_S = F_{DC} + F_{DB} + w(c_0 - c_H) + R_D H + K_E(\tau - \tau_c)c_B + S(c_B - c_S)$$

where

$$\begin{aligned} F_{DC} &= D_C \left. \frac{dc}{dz} \right|_0 && \text{chemical diffusion} \\ F_{DB} &= D_B \left. \frac{dc}{dz} \right|_0 && \text{bioirrigation} \end{aligned} \quad (10)$$

### 3.3 LINKING THE FIELD-MEASUREMENT PROGRAM TO PROPOSED PRISM INDICES

Figure 3-2 illustrates, in cartoon form, which field measurements are expected to contribute to which portions of the transport index equations, or Equation 10, above. In the following discussion, we describe how instrument outputs feed into these equations, and a few of the assumptions inherent in these approaches. In subsequent sections, we will discuss some modifications to this approach for the second field effort.

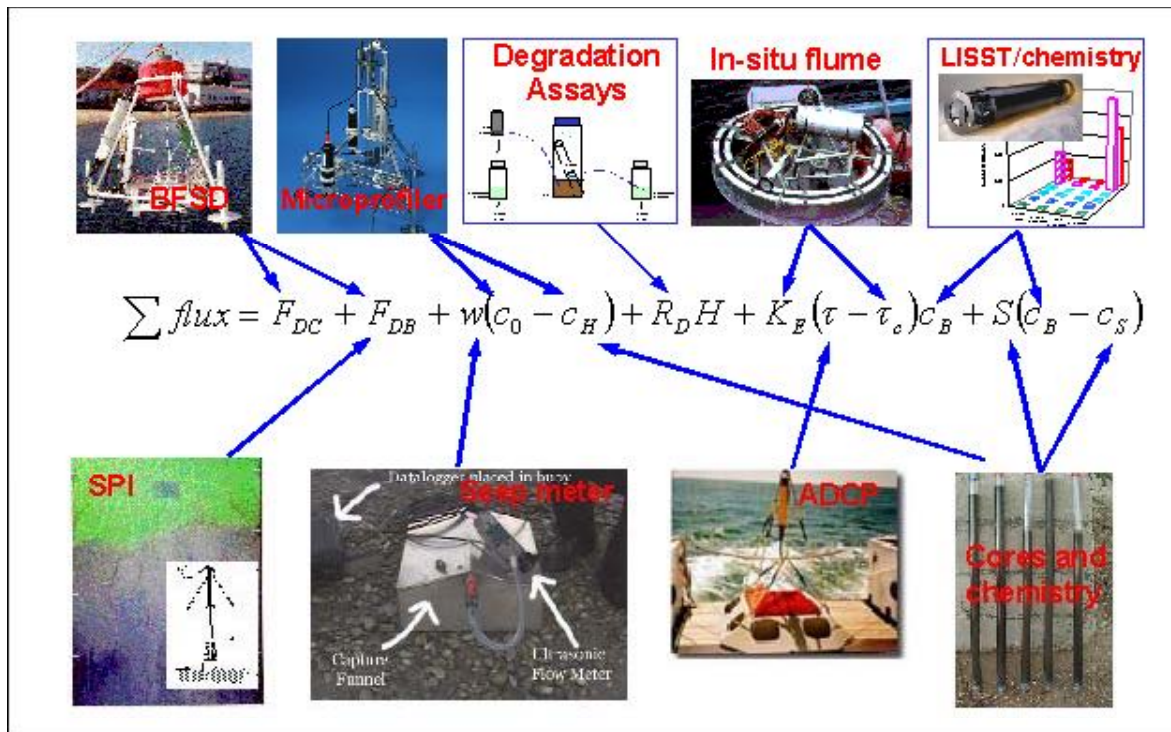


Figure 3-2. Input of field measurements into flux equation.

### 3.4 MATURITY OF TOOLS USED

The success of this project hinges on the effectiveness, success, and regulatory acceptance of a number of innovative technologies. A number of questions must be addressed, including: Are all of these technologies commercially available? Are they accepted for use at DoD sites? Have the reliability and accuracy of field measurements of individual processes been demonstrated and validated using the different field instruments? Where, if at all, has regulatory acceptance been achieved? What are their limitations? Table 3-1, below, addresses these questions for each of the instruments used.

The limitations (as well as strengths) are discussed in some detail in various sections of this report. The table below describes the maturity of the tools use. However, it should be pointed out that the goal of this project is NOT yet to provide data at a level capable of being used in a regulatory program. Rather, the goal is to provide the first simultaneous field measurements of the various processes that may control contaminant fate and transport in nearshore sediments. The results of these studies should provide insight into both what processes should be studied in greater detail at a research level, and what processes are most critical for a regulatory-level contaminated sediment management study. Ultimately, a subset of the measurements used in this study might be used in programs that will require regulatory acceptance. The figure below attempts to illustrate the feedback anticipated between the PRISM project, research and sediment management. Thus, while it is important that the tools used in the PRISM project have some degree of regulatory acceptance, and it is critical that the strengths, weaknesses and assumptions involved in each method are made clear, it is expected that any focused set of measurements that are determined to be critical to sediment management will be further standardized and validated under a program such as ESTCP. Table 3-1 below summarizes the technical maturity of the methods that are currently being applied within PRISM.



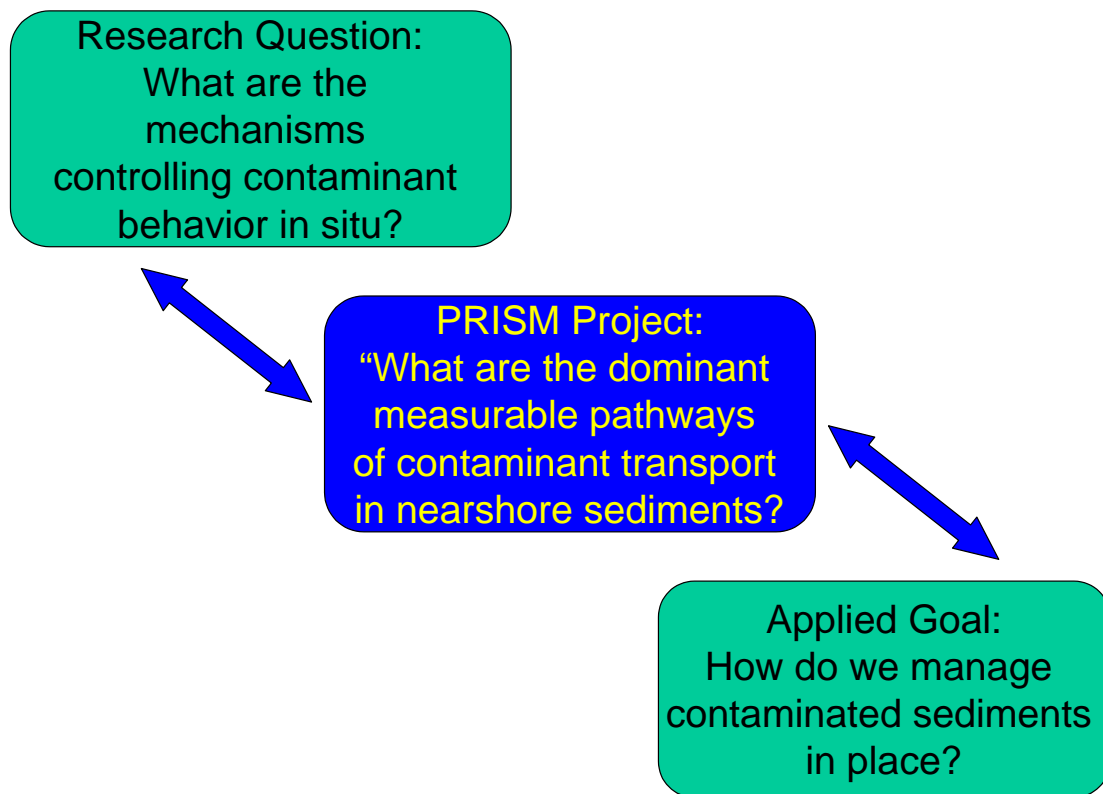


Figure 3-3. PRISM, research and applications.

Table 3-1. Technical maturity, acceptance level, and availability of PRISM methods.

<b>Tools; (lead lab)</b>	<b>Maturity/Acceptance/Availability</b>
BFSD; (SSD San Diego)	Metals – mature - CalCert PAHs – mature – CalCert Various BFSD units available via universities, ESTCP tech transfer makes tool available
Bioinhibited BFSD; (SSC San Diego)	Published observations, never used in this context; developmental; method to be critically assessed in project
Porewater gradients – squeeze and measure; (microgradients – SIO; composited cores – Battelle)	Standard, used in multiple regulatory programs Available via trained scientists
Porewater gradients – microprofiling; (SIO)	For “surrogates”, standard and COTS; not often used in regulatory programs, but extensively published in peer-reviewed literature; available via trained scientists
Tidal Seep Meter; (Cornell)	SSC validating under NAVFAC funding; can easily be produced
In situ Flume; (VIMS)	Several versions have published results; this flume being used at Anacostia and other contaminated sites with visibility; limited availability
LISST; (SSC San Diego)	Established, COTS. While there are some limitations to method, they will be extensively documented in this program
ADCP; (SSC San Diego)	Established, COTS; used in many regulatory programs
Sediment/Contaminant Geochemical signatures; (SSC San Diego)	Standard methods; SSC has developed and published use in contaminated sediment management; part of Navy sediment guidance; applications similar to those cited in EPA documents; available via most good analytical contractors
<sup>210</sup> Pb, <sup>7</sup> Be/ <sup>137</sup> Cs; (Battelle)	Standard; published, used extensively at sediment sites; available via many contractors
SPI Camera; (Germano and Associates)	Published, used at multiple sites; commercially available
SPI Camera – Time lapse; (Germano and Associates)	First application outside of Europe (second in world), but methods standard; commercially available
<sup>14</sup> C – labeled compound mineralization; (NRL)	NRL has published application at several sites; methods standard; published methods can be applied by trained microbiologists

### 3.5 HOW ARE THESE RESULTS THEN USED TO COMPARE AND RANK PATHWAYS?

For a given site, it is possible to compare these terms directly as flux rates. However, for some applications, additional insight can be gained by normalizing the terms to a scale that is relevant to risk reduction or recovery for the site. The risk/recovery level could be based on any number of criteria including water quality standards, sediment quality standards, or site-specific cleanup levels (for either sediment or porewater). An equivalent time scale can also be adopted for the site based on a target recovery time. A desired recovery rate (with the same dimension as our fluxes) can then be defined as

$$R_R = \frac{\Delta m}{\Delta t} = \frac{(c - c_C)H}{t_R}$$

where  $c$  is the current concentration in the sediment,  $c_C$  is the target level for cleanup or risk reduction and  $t_R$  is the target recovery time scale. Normalizing all flux terms to  $R_R$  results in a set of indices that reflect the relative contribution of various transport processes to site recovery or risk.

$$\begin{aligned} I_{DC} &= \frac{F_{DC}}{R_R} && \text{diffusion index} \\ I_{DS} &= \frac{F_{DB}}{R_R} && \text{bioirrigation index} \\ I_A &= \frac{w(c_0 - c_H)}{R_R} && \text{advection index} \\ I_B &= \frac{R_B H}{R_R} && \text{bio degradation index} \\ I_E &= \frac{K_E(\tau - \tau_c)c_B}{R_R} && \text{erosion index} \\ I_S &= \frac{S(c_B - c_S)}{R_R} && \text{sedimentation index} \end{aligned}$$

These indices then provide one non-dimensional yardstick for pathway ranking of important processes that can influence the fate of in-place sediment contamination. The interpretation of these indices would be that the larger indices are the more dominant pathways, and that pathways with  $I \geq 1$  or greater could represent an important process for recovery (or exposure). Of course, there are substantial risks in predicting long-term (years to decades) contaminant behavior based upon short-term (minutes to days) measurements. Furthermore, there are clear problems in examining or predicting changes over time from equations developed assuming steady state. For example, there is no doubt that PAH degradation rates vary substantially as concentration, nutrient level, temperature, and other factors vary. Thus, a measurement of instantaneous mineralization rates, while predictive of recovery times if all things remained constant, will not actually predict how long actual recovery of sediments would take by

biodegradation or how far that process will go. Parallel arguments can be made for all of the processes being discussed, since all measurements being made are short-term measurements (e.g., the SPI measurements are instantaneous snapshots, seep and BFSF are measured for ~72 hours, flume measurements for a few hours at the most). However, these problems exist for all current approaches to these issues. Currently, models try to predict recovery or exposure over time based either on short-term laboratory measurements (even less realistic, but more controllable, than field measurements) or based upon order-of-magnitude estimates based upon theoretical approaches. In any complex, multivariate process, predictions are just that. Having said this, this integrated field approach at least allows for the evaluation of multiple processes simultaneously and in common terms. This provides new insight into the relative importance of these processes in near-shore sediment environments. A critical assessment of the utility of this approach in sediment management, and a refinement of data evaluation processes as the project progresses, is one of the fundamental goals of this project.

It should be pointed out that these equations are only one way in which results can be applied to site management. Either all or a portion of the results can be used to refine Conceptual Site Models (CSMs), and specific data can be inserted into other models used to predict contaminant fate in terms of either risk or recovery. More details on approaches to data use are being summarized in a paper in preparation.

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## **4 Site II Field Program**

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## 4.1 SITE SELECTION AND OVERALL SAMPLING DESIGN

### Site selection

Ideally, PRISM fieldwork should be carried out at a minimum of two sites (choosing varied sites helps to widen the applicability of the developed methods to more situations), which meet the following criteria: 1) The sites should have a probability that they differ in dominant contaminant transport pathways (e.g., one site should be expected to be driven by diffusion, one by advection or biological processes or resuspension), 2) Sites should have sufficient levels of contaminants that fluxes and changes are detectable, 3) Sites should be undergoing RI/FS or some other remedial investigation so that data can contribute to the decision process *or* Site has recently (or will soon) be managed in situ, so that data can be used to evaluate efficacy (ideally, measurements would be made before and after a management approach was implemented), and 4) Investigators must have site access.

Other questions that were asked about potential sites include: 1) What are the contaminants of concern? 2) What are the regulatory drivers? 3) What stage of the process is this site at (e.g., dredging history assessment, feasibility or cleanup)? 4) What data are available? What form are the data in (hard copy or electronic)? 5) Are there constraints on ultimate management options? 6) What is the hydrodynamic regime?

After a thorough evaluation of potential field sites for the second demonstration (see Table 1 for a review of the sites considered), Pearl Harbor was selected for Site II. There is a mix of contaminants of concern, including metals and PAHs, increasing the probability that the methods applied will succeed. Extensive site studies have been published, and SSC and NRL scientists have been involved in numerous projects at the site, including portions of the RI/FS, as well as SERDP, ESTCP, Y0187 and ONR-funded work, so there is a large amount of information on the site, and access, support and collaboration have already been established. A wide range of management options, including in-place management, are being considered. However, due to the remoteness of the site, and the extensive equipment required on site for the field work, deployment Pearl Harbor is much more expensive than deployment at continental West and East Coast sites.



Table 4-1. Evaluation criteria for potential demonstration sites.

Site/Location	Principal CoCs	Reg. Driver	Site Assess. Status	Data On hand	General Characteristics - hyp. pathway	Constraints	User Demand	Regulator Interest	Additional Projects
NAS Alameda (SF Bay)	PAHs, PCBs, Metals	BRAC	FS	yes	Enclosed region, quiescent, small tidal influence		high	unknown	Ongoing FI/FS
Hunters Point Shipyard (SF Bay)	PCBs, Metals	BRAC	FS	yes	Tidal influence, potential groundwater intrusion, input from Yosemite Creek	Primarily PCB site, might not be suitable for current technologies, winter sampling not great	high	unknown	Ongoing RI/FS (Transport Studies/Battelle), Onshore Characterization (metals, PCBs)
Pearl Harbor	PAHs, PCBs, Metals	CERCLA/other	FS	yes	Tidal influence, wind driven transport	Ship traffic, deployment issue SIO, VIMs, shipping cost (may be defrayed), site access logistics	med	unknown	Cu Discharge Study, Flux Chamber Tests (?)
Elizabeth River (Norfolk)	PAHs, Metals	CERCLA/other	pre-RI	yes	Heavy ship traffic	Ship traffic, bridges, access to Navy Shipyard	low	unknown	ONR Harbor Processes, Fingerprinting Project, In Place Sediment Management

Table (cont'd). Evaluation criteria for potential demonstration sites.

Site/Location	Principal COPCs	Reg. Driver	Site Assess. Status	Data On hand	General Characteristics - hyp. pathway	Constraints	User Demand	Regulator Interest	Additional Projects
Bremerton Shipyard (Puget Sound)	PCBs, Metals, PAHs	CERCLA PCBs/Hg, TMDL for PAH and metals	dredging	no	Groundwater influence			unknown	
Dyes Inlet (Puget Sound)	PAHs, PCBs, Metals (As)	CERCLA cleanup ongoing		no	Groundwater influence			unknown	
Philadelphia Reserve Basin	PAHs, PCBs, Metals		dredging?	no	Enclosed region, quiescent, small tidal influence	Might be dredged; winter access?	high	unknown	
Coasters Harbor, RI	PAHs, Metals		Draft/final FS, focus on PAHs	?	resuspension of concern, flux from subsurface sediments	winter access?	high	unknown	Ongoing FS
Dodge Pond, CT	Hg			no	freshwater	Hg-not suitable for technologies; winter access?	med	unknown	

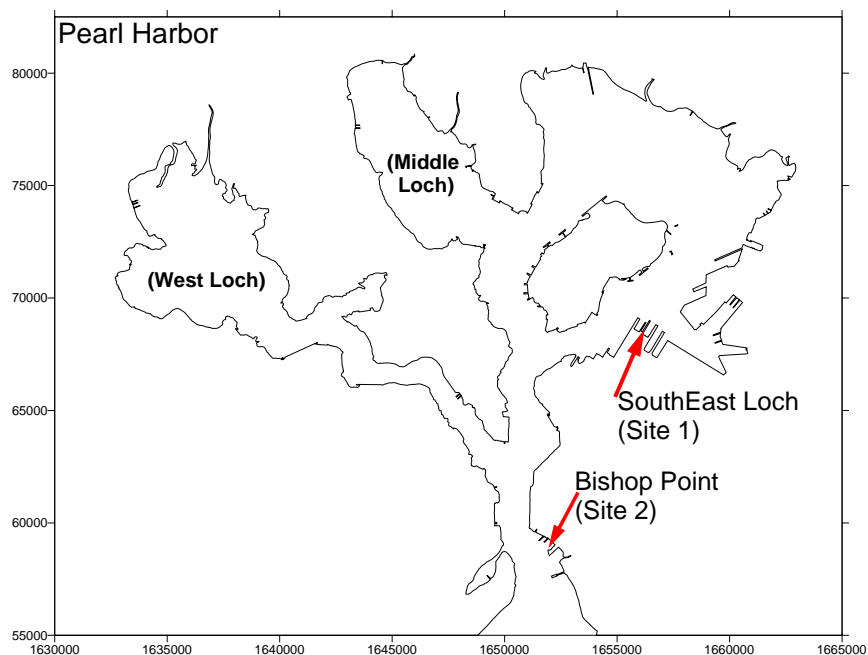


Figure 4-1. Map of Pearl Harbor with selected deployment sites highlighted.

### Site II field design discussion

The Navy and Ogden have carried out a preliminary RI/FS site assessment in a groundbreaking, regional way, examining the distribution of potentially anthropogenic chemicals and impact throughout the Pearl Harbor region. On a simple level, initial site assessment resulted in sediment strata that can fall into three basic categories: Type I - severely contaminated (and thus ready for examination of remedial options), Type II - questionable (elevated levels found, but impact not certain), or Type III - not of concern. For a region as large as the Pearl Harbor Naval Complex, resources are limited, and potential costs are vast. It is critically important that the management approaches selected for these sites focus limited resources to the most critical regions within the candidate sites - helping streamline rapid management of the most impacted regions, and pushing these sites towards delisting or closure.

Several strata within Pearl Harbor examined in the Ogden/Navy RI appear to lie squarely in the Type II category - possibly of concern, due to high levels, often of multiple contaminants, but requiring further evaluation of risk and recovery potential. In these cases, the next step towards cost-effective management of sediments is to focus on more detailed characterization of sediment strata, with potential remedial options in mind. In subsequent studies, Ogden and the Navy examined site-specific bioavailability and toxicity of various COPCs in surface sediments to various target organisms. While

evaluation of these data is still in progress, they suggest that, in spite of very high hazard quotients (HQs) for many strata (based on ER-M values), some strata may not pose great enough risks to justify their removal. Thus, while many remedies are under consideration, options include in-place management of selected sediment strata. However, such a decision will require a careful evaluation of potential pathways of contaminant exposure or recovery. A number of dynamic pathways may contribute to contaminant transport and exposure at contaminated sediment sites. These include the effects of bed transport, bioturbation, diffusion and advection, resuspension and deposition, and transformation and degradation. The relative rates of these processes help define the potential risk of in-place sediments, pathways of exposure that must be controlled and, potentially, mechanisms of natural recovery of the sediment. A risk assessment that considers in-place management options must address all these factors. An understanding of the relative importance of these processes at sites will focus conceptual site models (CSMs) and help risk managers balance these processes to minimize risk and, ideally, optimize recovery (e.g., Apitz and Chadwick 1999, 2001). Such an evaluation should provide sufficient information to support decisions about which sediments can responsibly be managed in place, how aggressively they should be monitored or contained, or whether they should be removed and managed ex situ. While still a demonstration project, PRISM addresses many of these issues on a site-specific basis.

The region around Southeast Loch (see Figure 1) represents an area for which PRISM work may help in remedy selection. This is a relatively small region, which PACDIV may choose to manage by containment, capping, removal or monitoring/no action. However, potential risks of these management options cannot be effectively projected without a good idea of the driving mechanisms behind of contaminant transport within the representative strata. Of particular concern in this regions are potential advective impact from groundwater flow, the impact of ship-induced resuspension and the relative impact of bioirrigation and diffusion on contaminant fluxes. The potential for PAHs to attenuate naturally in these sediments, and the rate of such degradation relative to deposition and transport mechanisms, are also important for management decisions. What options are indicated by sediment/contaminant geochemistry and transport? It is these issues that are addressed in a PRISM field deployment.

Furthermore, Bishop Point, which has undergone numerous studies by SSC-SD and other PRISM investigators, is a candidate for further investigation. Cu and other metals were found at this site to be more mobile (based on Benthic Flux Sampling Device (BFSD) measurements) than in the Middle Loch. Toxicity of these sediments was also higher than in Middle Loch. NRL measurements of instantaneous PAH mineralization rates, combined with PAH mapping and characterization at the site revealed exceptionally high levels and rapid mineralization of selected PAHs, suggesting both fresh input and high recovery potential. However, the integrated field demonstration was focused on mapping of surface sediment characteristics and thus did not examine relative rates of various exposure and recovery mechanisms, and did not address advective flow, resuspension issues (which are most likely significant due to extensive ship activity), bioirrigation and other relevant processes. PRISM deployment will look at the processes examined

previously in greater detail, as well as examining the relative rates of other risk and/or recovery pathways.

### Results of October 2002 field screening efforts

Figure 4-2 below lays out the sites considered for deployment. In October 2002, surface sediment grabs were collected and sent back to SSC San Diego for Rapid Sediment Characterization (RSC) screening. Figure 4-3 shows maps of contaminant distribution, based upon immunoassay results for organics and EDXRF for metals. The final figure in the series shows the sum of hazard quotients at each site, with each COPC normalized to ER-M. Table 4-2 presents the sample descriptions.

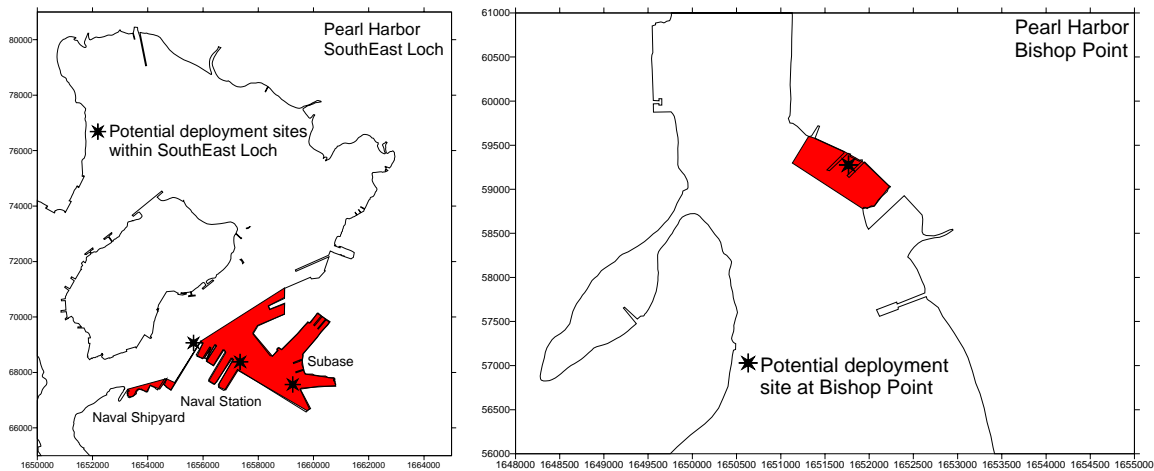


Figure 4-2. Proposed deployment sites.

Table 4-2. Descriptions of RSC samples.

Field ID	Color	Grain Size	Debris/Odor/Infauna	Time	Location	Comments
SL1RSC01	grey	sandy silt	shell debris	0936-0940	SouthEast Loch, Bravo Piers	end of B26
SL1RSC02	grey	fine silt	<b>fuel smell</b>	0944-0948	SouthEast Loch, Bravo Piers	B26
SL1RSC03	grey	fine silt	<b>fuel smell, shell debris</b>	0950-0958	SouthEast Loch, Bravo Piers	between B26/B25
SL1RSC04	dk grey	sandy silt	<b>oil sheen strong fuel smell</b>	1001-1003	SouthEast Loch, Bravo Piers	B25
SL1RSC05	dk grey	sandy silt		1005	SouthEast Loch, Bravo Piers	B24
SL1RSC06	dk grey	fine silt	<b>fuel smell, plant debris</b>	1010-1014	SouthEast Loch, Bravo Piers	end of B26 50' off pier
SL1RSC07	dk grey	fine silt		1016-1017	SouthEast Loch, Bravo Piers	B26 50' off pier
SL1RSC08	dk grey	fine silty clay grit	<b>fuel smell</b>	1020-1022	SouthEast Loch, Bravo Piers	between B26/B25 ~ 50' off pier
SL1RSC09	dk grey	fine silty clay	shell debris	1026-1031	SouthEast Loch, Bravo Piers	B25 ~ 50' off pier
SL1RSC10	brown	fine silt		1041-1042	SouthEast Loch, Ten Ten Dock	B3-B2, <i>USNS Walter Diehl (TA0-1)</i>
SL1RSC11	brown	fine silt		1043	SouthEast Loch, Ten Ten Dock	
SL1RSC12	lt grey	sandy silt		1049-1051	SouthEast Loch, Ten Ten Dock	
SL1RSC13	brown	fine mud		1055-1058	SouthEast Loch, Ten Ten Dock	
SL1RSC14	brown	fine silt		1100-1103	SouthEast Loch, Ten Ten Dock	
SL1RSC15	med brown	fine mud		1108	SouthEast Loch, Ten Ten Dock	75-100' off pier
SL1RSC16	grey	fine mud	shell debris	1111	SouthEast Loch, Ten Ten Dock	
SL1RSC17	grey brown	fine mud		1115	SouthEast Loch, Ten Ten Dock	
SL1RSC18	grey brown	fine mud		1120-1122	SouthEast Loch, Ten Ten Dock	up against pier
BP1RSC01	dk grey	sandy silt		1138-1141	Bishop Point, Alpha Docks	
BP1RSC02	grey brown	sandy silt		1144	Bishop Point, Alpha Docks	
BP1RSC03	grey brown	silty sand	tube worms shell debris	1146	Bishop Point, Alpha Docks	
BP1RSC04	dk grey brown	sandy silt	oil sheen fuel smell	1155	Bishop Point, Alpha Docks	
BP1RSC05	lt brown grey	sandy silt		1205-1208	Bishop Point, Alpha Docks	
BP1RSC06	med brown	silty sand	wood chips, pier debris	1210-1212	Bishop Point, Alpha Docks	end of Pier A3/A4

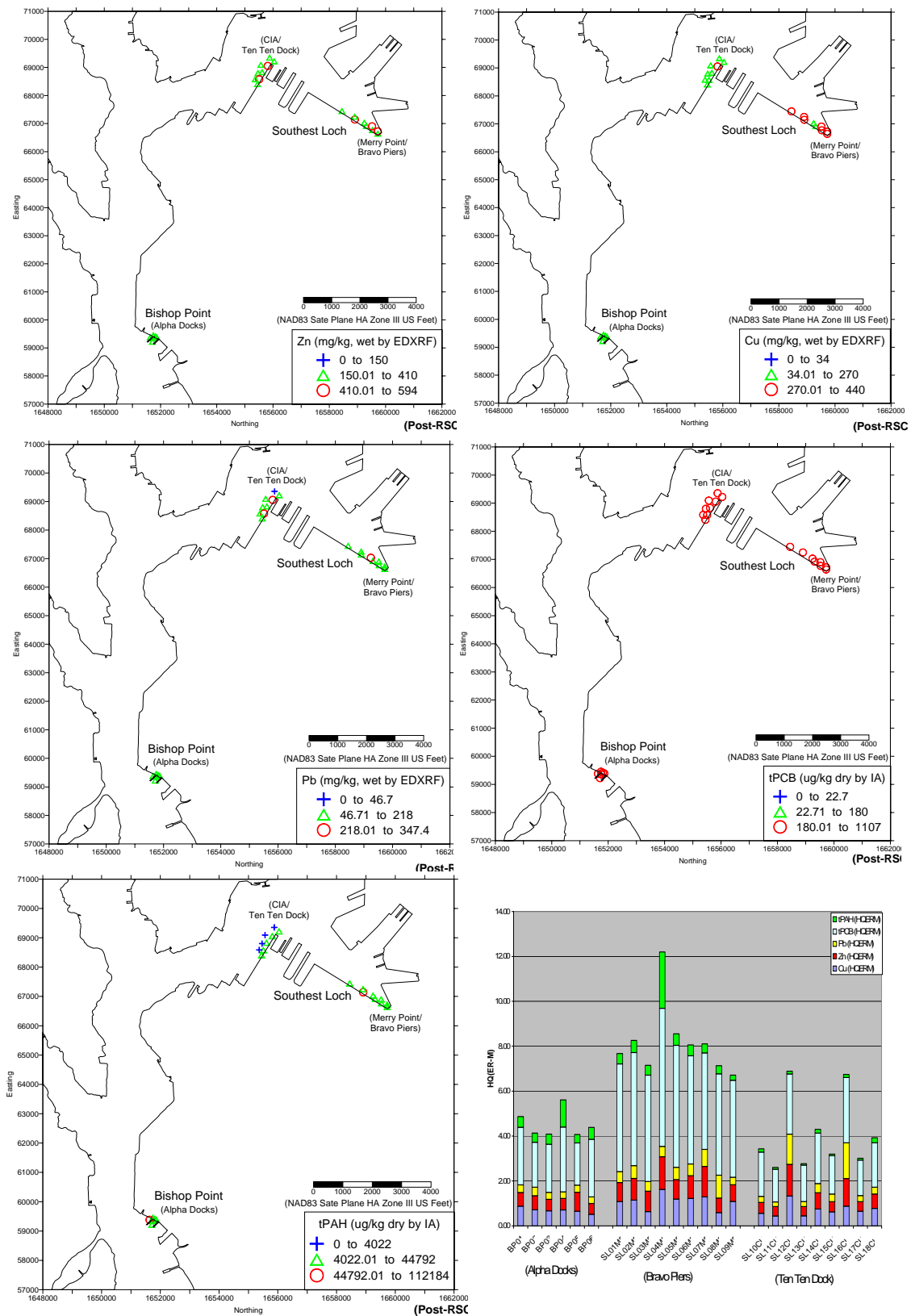


Figure 4-3. Contaminant distributions based on the screening samples.

Ultimately, the sites selected were Bishop Point and Merry Loch. Bishop Point was the site with the highest current velocities, and thus it was expected that resuspension, if important, would be most likely at this site. Merry Loch was expected to be impacted by potential groundwater intrusion, and perhaps introduction of COPCs via some old tanks. Thus, these sites provided the greatest probability of detectable signals and impacts by a range of processes.

While it can be seen above that PCBs are an important contaminant, they were not selected for study for a number of reasons 1) PAHs could be evaluated by a broader range of the tools applied, 2) analytical budgets would not allow for two types of organic analysis without a large sacrifice in sample numbers 3) consistency with Site I was considered desirable and 4) PCBs were expected to be less mobile, and thus less interesting, to the project.

### PRISM Demonstration II: Pearl Harbor Naval Complex - Sample Locations

Based upon the RSC results and locations, PRISM Sample Deployment IDs were generated, and designated as in Table 4-3 below. The PRISM measurements planned at each location are described in Table 4-4. Locations of these sites can be seen in Figure 4-4.

The field calendar shown in Table 4-5 below illustrates the schedule of measurements conducted at the site.

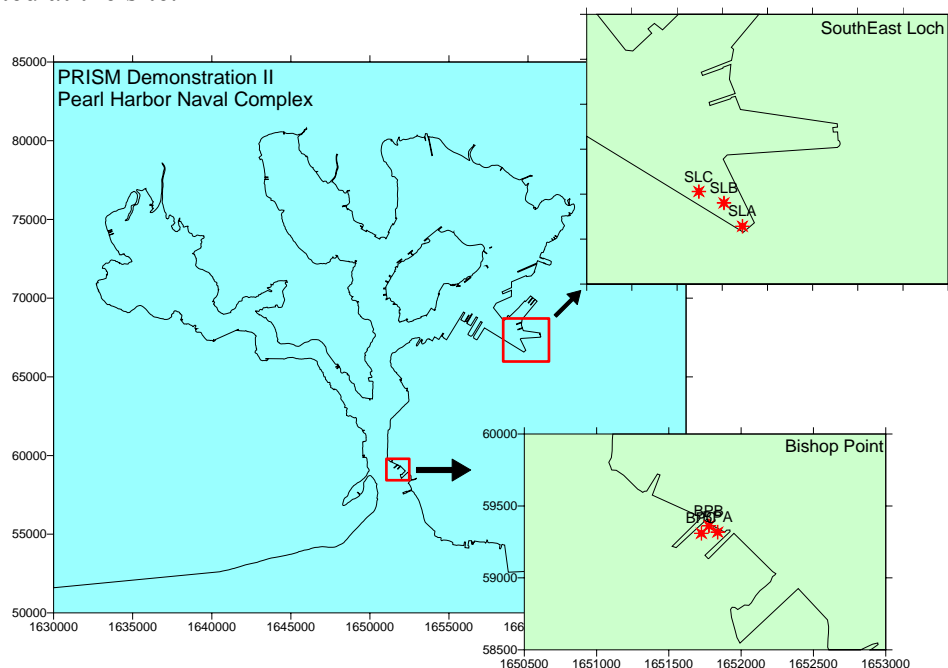


Figure 4-4. PRISM sample locations.

Table 4-3. Site II station locations and designations

RSC Sample ID	PRISM ID	Latitude	Longitude
SL1RSC01	SLA	21.3501167	157.9432667
SL1RSC07	SLB	21.3508333	157.9438667
SL1RSC08	SLC	21.3511833	157.9446833
BP1RSC01	BPA	21.3301500	157.9663667
BP1RSC02	BPB	21.3302333	157.9665167
BP1RSC05	BPC	21.3300667	157.9666833

Table 4-4. Station measurement matrix

PRISM ID	Latitude	Longitude	Current Meter	Sed Trap	BFSD	BFSD-B	General Coring	Age-Dated Cores*	Flume (x2)	Seep Meter**	Biodeg	Micro-profiling
SLA	21.3501167	157.9432667		x	x		x	After SPI	x	x	x	x
SLB	21.3508333	157.9438667	x	x	x		x	After SPI		x	x	x
SLC	21.3511833	157.9446833		x		x	x	After SPI	x	x	x	x
BPA	21.3301500	157.9663667	x	x	x		x	After SPI	x	x	x	x
BPB	21.3302333	157.9665167		x		x	x	After SPI		x	x	x
BPC	21.3300667	157.9666833	x	x	x		x	After SPI	x	x	x	x

\*Age-dated Cores: decide after SPI and shallow cores, area with least disturbance

\*\*Seep Meter: third one “flow-only”, no chemistry



Table 4-5. Pearl Harbor field sampling schedule.

## November 02

CREW	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	24	25. Ship SSC equipment	26	27	28	29	30. Equipment staging, setup for SPI
Dave Browning							Travel
Sabine Apitz							Travel
Ernie Arias						Travel	(POC)
Vikki Kirtay							
Amy Blake							
Wiebke Zeibis							
Joris Geiskes							
Mike Montgomery							
Other NRL							
Jeff Grovhoug							
Bart Chadwick							
Jon Groves							
Joel Guerrero							
Brad Davidson							
Chris Smith							
Ron Paulsen							
Jerome Maa							

## December 02

CREW	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1. Equipment staging, setup for SPI/coring	2. SPI camera BP. Setup for coring	3. SPI camera SEL. SPI recon meeting for BP	4. Multicore BP for solids, porewater, Cs, Be. BP core respirometry. SPI recon meeting for SEL	5. Multicore SEL for solids, porewater, Cs, Be. SEL core respirometry.	6. Deep core SEL and BP.	7. Stage BFSDs, sediment traps, current meters, and Seepage.
Dave Browning							
Sabine Apitz							Travel
Ernie Arias	(POC)	(POC)	(POC)	(POC)	(POC)	Travel	
Vikki Kirtay							
Amy Blake			Travel				
Wiebke Zeibis							
Joris Geiskes							
Mike Montgomery							
Other NRL							
Jeff Grovhoug					Travel		
Bart Chadwick						Travel	(POC)
Jon Groves							Travel
Joel Guerrero						Travel	
Brad Davidson						Travel	
Chris Smith							Travel
Ron Paulsen						Travel	
Jerome Maa							
Other VIMS							

## December 02

CREW	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	8. Stage BFSDs, Seepage, SPI, traps, current meters.	9. Deploy BFSDs, Seep Meters, SPI time lapse, current meters and sediment traps at BP.	10. Retrieve SPI time lapse at BP. Deploy SPI time lapse, sediment traps and current meters at SEL.	11. Retrieve SPI time series at SEL.	12. Retrieve BFSDs and Seep Meters at BP. Uncap sediment traps at BP. Demob SPI.	13. Deploy BFSDs and Seep Meters at SEL.	14.
Dave Browning					Travel		
Sabine Apitz							
Ernie Arias							
Vikki Kirtay							
Amy Blake				Travel			
Wiebke Zeibis							
Joris Geiskes							
Mike Montgomery							
Other NRL							
Jeff Grovhoug							
Bart Chadwick	(POC)	(POC)	(POC)	(POC)	(POC)	(POC)	(POC)
Jon Groves							
Joel Guerrero							
Brad Davidson							
Chris Smith							
Ron Paulsen							
Jerome Maa							
Other VIMS							

## December 02

CREW	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	15	16. Retrieve BFSDs and Seep Meters at SEL. Uncap sediment traps at SEL. Stage microprofile, BIO & SIO coring.	17. Deploy BFSD at SEL. Demob BFSD I, Seep meters. Multicore at SEL for microprofile, BIO & SIO cores.	18. Multicore at BP for microprofile, BIO & SIO cores.	19. Process microprofiles, BIO & SIO cores.	20. Retrieve BFSD at SEL. Demob BFSD II, multicore, microprofile, BIO. Ship gear.	21.
Dave Browning							
Sabine Apitz							
Ernie Arias							
Vikki Kirtay	Travel	(POC)	(POC)	(POC)	(POC)	(POC)	Travel
Amy Blake							
Wiebke Zeibis		Travel				Travel	
Joris Geiskes		Travel				Travel	
Mike Montgomery		Travel				Travel	
Chris Osburn		Travel				Travel	
Jeff Grovhoug				Travel			
Bart Chadwick	(POC)	Travel					
Jon Groves							Travel
Joel Guerrero						Travel	
Brad Davidson						Travel	
Chris Smith			Travel				
Ron Paulsen			Travel				
Jerome Maa							
Other VIMS							

## January 02

CREW	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	5. Equipment staging	6. Flume Assembly	7. Recover sediment traps and current meters at BP. Flume Deployment at BP-1	8. Recover sediment traps and current meters at SEL. Flume deployment at BP-2, SEL-1.	9. Flume deployment at SEL-2; contingency	10. Contingency. Demob Flume, traps, current meters	11.
Dave Browning							
Sabine Apitz							
Ernie Arias	Travel	(POC)	(POC)	(POC)	(POC)	Travel	
Vikki Kirtay							
Amy Blake		Travel					Travel
Wiebke Zeibis							
Joris Geiskes							
Mike Montgomery							
Other NRL							
Jeff Grovhoug							
Bart Chadwick							
Jon Groves	Travel						Travel
Joel Guerrero							
Brad Davidson							
Chris Smith							
Ron Paulsen							
Jerome Maa	Travel					Travel	
Other VIMS	Travel					Travel	

Legend	
Germano & Assoc.	
SSCSD	
SIO	
NRL	
Cornell	
VIMS	

## **5 Site II Field Results**

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## **5.1 Sediment Profile Imaging Survey**

### **Introduction**

As part of a multidisciplinary research program to investigate contaminant transport pathways for coastal sediments, Germano & Associates, Inc. (G&A) performed a Sediment Profile Imaging (SPI) survey in selected areas off Bishop Point and in SE Loch (Pearl Harbor, Hawaii; Figure 5-1) during the first week of December, 2002. The purpose of the SPI survey was to delineate gradients in sediment grain-size, redox depth, small-scale boundary roughness, and benthic community assemblage in the general areas where more detailed investigations were being carried out by the other PRISM team investigators. In addition to the general survey to characterize spatial variability at these two study sites, SPI technology was also used at one station at both Bishop Point and SE Loch for an extended (24 hour) deployment to investigate what temporal changes, if any, would occur in bioturbation depths at these two locations.

### **Materials And Methods**

The regional SPI survey at Bishop Point took place on December 2, 2002; three to five replicate images were taken at 8 locations at the north end of the site near the quay wall (Figure 5-2). A total of 14 stations were surveyed the following day (December 3, 2002) at SE Loch (Figure 5-3); a minimum of three up to a maximum of eight replicate images were taken at each station (Appendix A). The following week, the SPI camera was deployed in each of these areas for 24 hours, with the internal camera settings adjusted to take an image every 5 minutes to create a time-lapse movie of changes in bioturbation depth. The overnight deployment at Bishop Point took place on December 9-10, 2002 at Station C (Figure 5-2), followed by the overnight deployment at SE Loch on December 10-11, 2002, at Station B (Figure 5-3).

At the beginning of the survey, the time on the sediment profile camera's internal data logger was synchronized with the internal clock on the computerized navigation system to Pacific Time. Three replicate images were taken at each station; each SPI replicate is identified by the time recorded on the film and on disk along with vessel position. Even though multiple images were taken at each location, each image was assigned a unique frame number by the data logger and cross-checked with the time stamp in the navigational system's computer data file. Redundant sample logs were kept by the field crew.

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were fired on deck at the beginning and end of each survey day to verify that all internal electronic

systems were working to design specifications and to provide a color standard against which final film emulsion could be checked for proper color balance. Charged spare batteries were carried in the field at all times to insure uninterrupted sample acquisition. After deployment of the camera at each station, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth to acquire a profile image. If images were been missed (frame counter indicator) or the penetration depth was insufficient (penetration indicator), weights were added or removed and additional replicates taken. Changes in prism weight amounts, the presence or absence of mud doors, and chassis stop positions were noted in the log for each replicate image. All film taken was developed in the field at the end of each survey day to verify successful data acquisition; strict controls were maintained for development temperatures, times, and chemicals to insure consistent density on the film emulsion. The film was then visually inspected under magnification to determine whether any stations needed resampling.

Following completion of field operations, the color slides were scanned and stored in photo-CD format by ProLab, Inc., Seattle, WA. A total of 58 digital images were analyzed from this survey using Image Pro® (Media Cybernetics, Inc.). Calibration information was determined by measuring 1-cm gradations from the Kodak® Color Separation Guide. This calibration information was applied to all SPI images analyzed. Linear and area measurements were recorded as number of pixels and converted to scientific units using the calibration information.

Measured parameters were recorded on a Microsoft® Excel spreadsheet. These data were subsequently checked by G&A's senior scientist (Dr. J. Germano) as an independent quality assurance/quality control review of the measurements before final interpretation was performed.

## **Measuring, Interpreting, and Mapping SPI Parameters**

### *Sediment Type*

The sediment grain-size major mode and range were visually estimated from the color slides by overlaying a grain-size comparator that was at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) with the SPI camera. Seven grain-size classes were on this comparator:  $>4 \phi$ ,  $4-3 \phi$ ,  $3-2 \phi$ ,  $2-1 \phi$ ,  $1-0 \phi$ ,  $0 - (-)1 \phi$ ,  $< -1 \phi$ . The lower limit of optical resolution of the photographic system was about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt ( $\geq 4 \phi$ ). The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses.

The comparison of the SPI images with Udden-Wentworth sediment standards photographed through the SPI optical system was also used to map near-surface stratigraphy such as sand-over-mud and mud-over-sand. When mapped on a local scale, this stratigraphy can provide information on relative transport magnitude and frequency.

#### *Prism Penetration Depth*

The SPI prism penetration depth was measured from the bottom of the image to the sediment-water interface. The average penetration depth was determined by measuring across the entire cross-sectional image. Linear maximum and minimum depths of penetration were also measured. Maximum, minimum, and average penetration depths were recorded in the data file.

Prism penetration is potentially a noteworthy parameter; if the number of weights used in the camera is held constant throughout a survey, the camera functions as a static-load penetrometer. Comparative penetration values from sites of similar grain size give an indication of the relative water content of the sediment. Highly bioturbated sediments and rapidly accumulating sediments tend to have the highest water contents and greatest prism penetration depths.

The depth of the camera's penetration into the bottom also reflects the bearing capacity and shear strength of local sediments. Overconsolidated or relic sediments and shell-bearing sands resist camera penetration. Highly bioturbated, sulfidic, or methanogenic muds are the least consolidated, and deep penetration is typical. Seasonal changes in camera prism penetration are typically observed at the same station and are related to the control of sediment geotechnical properties by bioturbation (Rhoads and Boyer 1982). The effect of water temperature on bioturbation rates appears to be important in controlling both biogenic surface relief and prism penetration depth (Rhoads and Germano 1982).

#### *Small-Scale Surface Boundary Roughness*

Surface boundary roughness was determined by measuring the vertical distance (parallel to the film border) between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over a horizontal distance of 15 cm typically ranges from 0.02 to 3.8 cm, and may be related to either physical structures (ripples, rip-up structures, mud clasts) or biogenic features (burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

The camera must be level in order to take accurate boundary roughness measurements. In sandy sediments, boundary roughness can be a measure of sand wave height. On silt-



clay bottoms, boundary roughness values often reflect biogenic features such as fecal mounds or surface burrows.

#### *Thickness of Depositional Layers*

Because of the camera's unique design, SPI can be used to detect the thickness of depositional and dredged material layers. SPI is effective in measuring layers ranging in thickness from 20 cm (the height of the SPI optical window) to 1 mm. During image analysis, the thickness of the newly deposited sedimentary layers can be determined by measuring the linear distance between the pre- and post-disposal sediment-water interface. Recently deposited material is usually evident because of its unique optical reflectance and/or color relative to the underlying material representing the pre-disposal surface. Also, in most cases, the point of contact between the two layers is clearly visible as a textural change in sediment composition, facilitating measurement of the thickness of the newly deposited layer.

#### *Mud Clasts*

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity, e.g., decapod foraging, intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in SPI images. During analysis, the number of clasts was counted, the diameter of a typical clast was measured, and their oxidation state (discussed below) was assessed. The abundance, distribution, oxidation state, and angularity of mud clasts can be used to make inferences about the recent pattern of seafloor disturbance in an area.

Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. In SPI images, the oxidation state is apparent from the reflectance; see Section 2.1.6. Also, once at the sediment-water interface, these mud clasts are subject to bottom-water oxygen concentrations and currents. Evidence from laboratory microcosm observations of reduced sediments placed within an aerobic environment indicates that oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6 to 12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of the mud clasts are also revealing. Mud clasts may be moved and broken by bottom currents and animals (macro- or meiofauna; Germano 1983). Over time, large angular clasts become small and rounded.

#### *Apparent Redox Potential Discontinuity Depth*

Aerobic near-surface marine sediments typically have higher reflectance relative to underlying hypoxic or anoxic sediments. Surface sands washed free of mud also have higher optical reflectance than underlying muddy sands. These differences in optical reflectance are readily apparent in SPI images; the oxidized surface sediment contains

particles coated with ferric hydroxide (an olive or tan color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally grey to black. The boundary between the colored ferric hydroxide surface sediment and underlying grey to black sediment is called the apparent redox potential discontinuity (RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment porewaters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment oxygen demand (SOD), the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated porewaters must be considered with caution. The actual RPD is the boundary or horizon that separates the positive Eh region of the sediment column from the underlying negative Eh region. The exact location of this  $Eh = 0$  boundary can be determined accurately only with microelectrodes; hence, the relationship between the change in optical reflectance, as imaged with the SPI camera, and the actual RPD can be determined only by making the appropriate *in situ* Eh measurements. For this reason, the optical reflectance boundary, as imaged, was described in this study as the “apparent” RPD and it was mapped as a mean value. In general, the depth of the actual  $Eh = 0$  horizon will be either equal to or slightly shallower than the depth of the optical reflectance boundary. This is because bioturbating organisms can mix ferric hydroxide-coated particles downward into the bottom below the  $Eh = 0$  horizon. As a result, the apparent mean RPD depth can be used as an estimate of the depth of porewater exchange, usually through porewater irrigation (bioturbation). Biogenic particle mixing depths can be estimated by measuring the maximum and minimum depths of imaged feeding voids in the sediment column. This parameter represents the particle mixing depths of head-down feeders, mainly polychaetes.

The rate of depression of the apparent RPD within the sediment is relatively slow in organic-rich muds, on the order of 200 to 300 micrometers per day; therefore this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the apparent RPD is also slow (Germano 1983). Measurable changes in the apparent RPD depth using the SPI optical technique can be detected over periods of 1 or 2 months. This parameter is used effectively to document changes (or gradients) that develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates,

seasonal hypoxia, SOD, and infaunal recruitment. Time-series RPD measurements following a disturbance can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos (Rhoads and Germano 1986).

The apparent mean RPD depth also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This scouring can wash away fines and shell or gravel lag deposits, and can result in very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette et al. 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance at this boundary. This contrast is related to the interactions among the degree of organic loading, the bioturbation activity in the sediment, and the concentrations of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase SOD and, subsequently, sulfate reduction rates and the associated abundance of sulfide end products. This results in more highly reduced, lower-reflectance sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material such as phytoplankton or other naturally-occurring organic detritus, dredged material, and sewage sludge.

#### *Sedimentary Methane*

If organic loading is extremely high, porewater sulfate is depleted and methanogenesis occurs. The process of methanogenesis is indicated by the appearance of methane bubbles in the sediment column, and the number and total area covered by all methane pockets is measured. These gas-filled voids are readily discernable in SPI images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas bubble).

#### *Infaunal Successional Stage*

The mapping of infaunal successional stages is readily accomplished with SPI technology. These stages are recognized in SPI images by the presence of dense assemblages of near-surface polychaetes and/or the presence of subsurface feeding voids; both may be present in the same image. Mapping of successional stages is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in “the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest..., our definition does not demand a sequential appearance of particular invertebrate species or genera” (Rhoads and Boyer 1982). This theory is presented in Pearson and Rosenberg

(1978) and further developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

This continuum of change in animal communities after a disturbance (primary succession) has been divided subjectively into three stages: Stage I is the initial community of tiny, densely populated polychaete assemblages; Stage II is the start of the transition to head-down deposit feeders; and Stage III is the mature, equilibrium community of deep-dwelling, head-down deposit feeders.

After an area of bottom is disturbed by natural or anthropogenic events, the first invertebrate assemblage (Stage I) appears within days after the disturbance. Stage I consists of assemblages of tiny tube-dwelling marine polychaetes that reach population densities of  $10^4$  to  $10^6$  individuals per  $m^2$ . These animals feed at or near the sediment-water interface and physically stabilize or bind the sediment surface by producing a mucous “glue” that they use to build their tubes. Sometimes deposited dredged material layers contain Stage I tubes still attached to mud clasts from their location of origin; these transported individuals are considered as part of the *in situ* fauna in our assignment of successional stages.

If there are no repeated disturbances to the newly colonized area, then these initial tube-dwelling suspension or surface-deposit feeding taxa are followed by burrowing, head-down deposit-feeders that rework the sediment deeper and deeper over time and mix oxygen from the overlying water into the sediment. The animals in these later-appearing communities (Stage II or III) are larger, have lower overall population densities (10 to 100 individuals per  $m^2$ ), and can rework the sediments to depths of 3 to 20 cm or more. These animals “loosen” the sedimentary fabric, increase the water content in the sediment, thereby lowering the sediment shear strength, and actively recycle nutrients because of the high exchange rate with the overlying waters resulting from their burrowing and feeding activities.

#### *Organism-Sediment Index*

The Organism-Sediment Index (OSI) is a summary mapping statistic that is calculated on the basis of four independently measured SPI parameters: apparent mean RPD depth, presence of methane gas, low/no dissolved oxygen at the sediment-water interface, and infaunal successional stage. Table 5-1 shows how these parameters are summed to derive the OSI.

The highest possible OSI is +11, which reflects a mature benthic community in relatively undisturbed conditions (generally a good yardstick for high benthic habitat quality). These conditions are characterized by deeply oxidized sediment with a low inventory of anaerobic metabolites and low SOD, and by the presence of a climax (Stage III) benthic community. The lowest possible OSI is -10, which indicates that the sediment has a high inventory of anaerobic metabolites, has a high oxygen demand, and is azoic. In our

mapping experience over the past 15 years, we have found that OSI values of 6 or less indicate that the benthic habitat has experienced physical disturbance, organic enrichment, or excessive bioavailable contamination in the recent past.

Table 5-1. Calculation of the SPI Organism-Sediment Index.

PARAMETER	INDEX VALUE
<b>A. Mean RPD Depth (choose one)</b>	
0.00 cm	0
> 0-0.75 cm	1
0.76-1.50 cm	2
1.51-2.25 cm	3
2.26-3.00 cm	4
3.01-3.75 cm	5
> 3.75 cm	6
<b>B. Successional Stage (choose one)</b>	
Azoic	-4
Stage I	1
Stage I → II	2
Stage II	3
Stage II → III	4
Stage III	5
Stage I on III	5
Stage II on III	5
<b>C. Chemical Parameters (choose one or both if appropriate)</b>	
Methane Present	-2
No/Low Dissolved Oxygen <sup>a</sup>	-4
<b>Organism-sediment Index = Total of above subset indices (A+B+C)</b>	
<b>Range: -10 to +11</b>	

<sup>a</sup> This is not based on a Winkler or polarigraphic electrode measurement, but on the imaged evidence of reduced, low reflectance (i.e., high-oxygen-demand) sediment at the sediment-water interface.

## Using SPI Data to Assess Benthic Health

While various measurements of water quality such as dissolved oxygen, contaminants, or nutrients are often used to assess regional ecological health, interpretation is difficult because of the transient nature of water-column phenomena. Measurement of a particular value of any water-column variable represents an instantaneous “snapshot” that can change within minutes after the measurement is taken. By the time an adverse signal in the water column such as a low dissolved oxygen concentration is persistent, the system may have degraded to the point where resource managers can do little but map the areal extent of the phenomenon while gaining a minimal understanding of factors contributing to the overall degradation.

The seafloor, on the other hand, is a long-term time integrator of sediment and overlying water quality; values for any variable measured are the result of physical, chemical, and biological interactions on time scales much longer than those present in a rapidly moving fluid. The seafloor is thus an excellent indicator of environmental health, both in terms of historical impacts and of future trends for any particular variable.

Physical measurements made with the SPI system from profile images provide background information about gradients in physical disturbance (caused by dredging, disposal, trawling, or storm resuspension and transport) in the form of maps of sediment grain size, boundary roughness, fabrics, and structures. The concentration of organic matter and the SOD can be inferred from the optical reflectance of the sediment column and the apparent RPD depth. Organic matter is an important indicator of the relative value of the sediment as a carbon source for both bacteria and infaunal deposit feeders. SOD is an important measure of ecological health; oxygen can be depleted quickly in sediment by the accumulation of organic matter and by bacterial respiration, both of which place an oxygen demand on the porewater and compete with animals for a potentially limited oxygen resource (Kennish 1986).

The apparent RPD depth is useful in assessing the quality of a habitat for epifauna and infauna from both physical and biological points of view. The apparent RPD depth in profile images has been shown to be directly correlated to the quality of the benthic habitat in polyhaline and mesohaline estuarine zones (Rhoads and Germano 1986; Revelas et al. 1987; Valente et al. 1992). Controlling for differences in sediment type and physical disturbance factors, apparent RPD depths < 1 cm can indicate chronic benthic environmental stress or recent catastrophic disturbance.

The distribution of successional stages in the context of the mapped disturbance gradients is one of the most sensitive indicators of the ecological health of the seafloor (Rhoads and Germano 1986). The presence of Stage III equilibrium taxa (mapped from subsurface feeding voids as observed in profile images) can be a good indication of high benthic

habitat stability and relative “health.” A Stage III assemblage indicates that the sediment surrounding these organisms has not been disturbed severely in the recent past and that the inventory of bioavailable contaminants is relatively small. These inferences are based on past work, primarily in temperate latitudes, showing that Stage III species are relatively intolerant to sediment disturbance, organic enrichment, and sediment contamination. Stage III species expend metabolic energy on sediment bioturbation (both particle advection and porewater irrigation) to control sediment properties, including porewater profiles of sulfate, nitrate, and RPD depth in the sedimentary matrix near their burrows or tubes (Aller and Stupakoff 1996; Rice and Rhoads 1989). This bioturbation results in an enhanced rate of decomposition of polymerized organic matter by stimulating microbial decomposition (“microbial gardening”). Stage III benthic assemblages are very stable and are also called climax or equilibrium seres.

The metabolic energy expended in bioturbation is rewarded by creating a sedimentary environment where refractory organic matter is converted to usable food. Stage III bioturbation has been likened to processes such as stirring and aeration used in tertiary sewage treatment plants to accelerate organic decomposition. These processes can be interpreted as a form of human bioturbation. Physical disturbance, contaminant loading, and/or over-enrichment result in habitat destruction and in local extinction of the climax seres. Loss of Stage III species results in the loss of sediment stirring and aeration and may be followed by a buildup of organic matter (eutrophication) of the sediment. Because Stage III species tend to have relatively conservative rates of recruitment, intrinsic population increase, and ontogenetic growth, they may not reappear for several years once they are excluded from an area.

The presence of Stage I seres (in the absence of Stage III seres) can indicate that the bottom is an advanced state of organic enrichment or has received high contaminant loading. Unlike Stage III communities, Stage I seres have a relatively high tolerance for organic enrichment and contaminants. These opportunistic species have high rates of recruitment, high ontogenetic growth rates, and live and feed near the sediment-water interface, typically in high densities. Stage I seres often co-occur with Stage III seres in marginally enriched areas. In this case, Stage I seres feed on labile organic detritus settling onto the sediment surface, while the subsurface Stage III seres tend to specialize on the more refractory buried organic reservoir of detritus.

Stage I and III seres have dramatically different effects on the geotechnical properties of the sediment (Rhoads and Boyer 1982). With their high population densities and their feeding efforts concentrated at or near the sediment-water interface, Stage I communities tend to bind fine-grained sediments physically, making them less susceptible to resuspension and transport. Just as a thick cover of grass will prevent erosion on a terrestrial hillside, so too will these dense assemblages of tiny polychaetes serve to stabilize the sediment surface. Conversely, Stage III taxa increase the water content of

the sediment and lower its shear strength through their deep burrowing and pumping activities, rendering the bottom more susceptible to erosion and resuspension. In shallow areas of fine-grained sediments that are susceptible to storm-induced or wave orbital energy, it is quite possible for Stage III taxa to be carried along in the water column in suspension with fluid muds. When redeposition occurs, these Stage III taxa can become quickly re-established in an otherwise physically disturbed surface sedimentary fabric.

## **Results**

A complete set of all the data measured from each image is presented in Appendix A. The results from each site will be presented in separate sections.

### **Bishop Point**

#### *Grain Size*

The sediments throughout the entire area surveyed were primarily fine-grained (major mode  $> 4\phi$ ) sandy silts, with the exception of Station A, which had a major mode of very fine sand. Most stations showed evidence of a surface layer of fine- to very-fine carbonate sand (Figure 5-4). Station A, located right next to the quay wall, had organically-enriched, silty, very-fine sands in three of the five replicate images (Figure 5-5). Station A had the most pronounced organic-loading of all locations sampled in this area.

#### *Surface Boundary Roughness*

The average small-scale surface boundary roughness at Bishop Point ranged from 0.95 to 5.93 cm across the locations surveyed (Appendix A; Figure 5-6). The majority of the roughness elements measured were biogenic structures (projecting tubes or burrow openings) that could be quite prominent in areas where burrowing crustaceans (ghost shrimp) were present (Figure 5-7). The large roughness values found at Station H were sampling artifacts caused by disturbance features from the camera landing in the same spot where it had previously sampled (Figure 5-8).

#### *Prism Penetration Depth*

With sediment grain-size fairly uniform across the entire study area, the variation in prism penetration was a good indicator of relative sediment shear strength as a function of biological mixing depth (Figure 5-9); at two of the three stations where prism penetration was less than 10 cm (approximately half the height of the camera's front faceplate), the low penetration values were caused by the camera landing on hard rocks (Station D) or submarine pipes (underwater welding practice structures; Station G) in one or more of the replicate deployments. Even though the sediments at Station A had a major mode of very fine sand, the relative sediment shear strength was comparable to that found at the remaining stations dominated by fine-grained sediments; a high amount of biological reworking combined with a high inventory of organic material (plant debris)



dilated the sediments sufficiently at this location to allow the greatest prism penetration (Figure 5-10), indicating that the sediments at this location would be the most susceptible to erosion. The overall average prism penetration for the Bishop Point site was 9.16 cm.

#### *Apparent Redox Potential Discontinuity Depth*

The distribution of mean apparent RPD depths is shown in Figure 5-11; the average station values at Bishop Point ranged from a minimum of 2.06 cm to a maximum of 4.83 cm, with an overall site mean value of 2.90 cm. The within-station variability in mean apparent RPD depths was strongly related to variability in bioturbation activity; the best example of this phenomenon could be found at Station C, where sediment reworking activities of resident ghost shrimp fluidized the sediments and reworked oxygenated porewater/particles down to depths in excess of 10 cm (Figure 5-12).

#### *Infaunal Successional Stage*

The distribution of infaunal successional stages was fairly homogeneous and therefore not mapped; all stations showed evidence of Stage III deposit-feeding assemblages, and with the exception of those replicate images where the camera prism could not penetrate, subsurface feeding voids were present in most images (Appendix A). Despite the amount of ship traffic/anthropogenic activity in this area, the impact to the benthic habitat was not great enough to adversely affect the maintenance or development of a mature, deposit-feeding equilibrium community at any of the locations sampled.

#### *Void Ratio*

One parameter of potential interest to the investigations being conducted in this area is the void ratio, or what percentage of the cross-sectional area of the sediment is occupied by feeding voids. The amount that a sediment is “dilated” by bioturbational activities can have an effect on the erosion potential for an area of bottom and also affect the flux rate of porewater with the overlying water column. The void ratio at Bishop Point was generally rather low, less than 2% across the entire area surveyed (Figure 5-13). The variation in average void ratio across the area surveyed did not vary as a function of other measured SPI physical parameters (Table 5-2).

#### *Organism-Sediment Index*

The spatial distribution of median OSI values throughout the study area can be seen in Figure 5-14. An OSI of +6 or less typically indicates that a benthic habitat has undergone disturbance, either from physical forces, eutrophication, or excessive bioavailable contamination in the recent past. There were no stations with median OSI values less than +6, and only two replicate images from Station A had individual values of +5, reflecting the disturbance from the obvious organic loading that occurred at this location.

Table 5-2. Summary of Selected Average Measurements at Bishop Point Stations.

STATION NAME	Station Average Penetration (cm)	Station Average RPD (cm)	Station Average Boundary Roughness (cm)	Station Average Void Ratio	Station Maximum Void Depth (cm)
BPA	12.54	2.06	1.67	1.48%	14.32
BPB	10.51	2.30	2.43	0.61%	11.21
BPC	11.85	4.83	1.58	0.61%	10.10
BPD	6.13	2.40	1.40	0.28%	6.65
BPE	10.30	2.69	1.65	0.74%	7.92
BPF	6.29	2.17	2.22	0.51%	7.29
BPG	4.09	4.42	0.95	0.09%	12.38
BPH	11.59	2.37	5.93	0.40%	9.02
	=====	=====	=====	=====	=====
<b>MEAN</b>	9.16	2.90	2.23	0.59%	9.86
<b>STD DEV</b>	3.18	1.08	1.57	0.41%	2.66
<b>CV</b>	34.7%	37.2%	70.2%	70.4%	27.0%

## Southeast Loch

### *Grain Size*

The sediments at all stations except two in the area surveyed at SE Loch were organic-rich, fine-grained sandy silts with a major mode of  $> 4\phi$ . Two of the stations closest to the dock walls (D and K) had hard sand with coral rubble or rocks, in marked contrast to the sediments at the rest of the locations (Figure 5-15). The thin surface layer of fine to very-fine sand that was so common at many of the Bishop Point stations was noticeably absent at the SE Loch sampled locations.

### *Surface Boundary Roughness*

The average small-scale surface boundary roughness at SE Loch ranged from 0.73 to 4.34 cm (Figure 5-16). With the exception of the two stations that were located on hard bottom, all the small-scale roughness elements were due to topographic irregularities created by biogenic re-working of the sediments. There was no evidence of sediment transport or erosion at any location.

### *Prism Penetration Depth*

The prism penetration depth across the area surveyed at SE Loch was generally greater than that at Bishop Point (Figure 5-17). With the exception of a few stations, this area was generally characterized by sediments with relatively low shear strength due to the extensive amount of biological reworking by macrofauna in this area (Figure 5-18). Most of the cross-sectional profiles showed very homogeneous sandy silts with numerous

backfilled voids, typical of highly bioturbated sediments that would have relatively uniform pore-water dissolved nutrient profiles from the extensive re-working. The overall average prism penetration for the site was 10.82 cm (Table 5-3).

#### *Apparent Redox Potential Discontinuity Depth*

The distribution of mean apparent RPD depths is shown in Figure 5-19; average values across the area surveyed ranged from a minimum of 2.08 cm at Station A to a maximum of 6.62 cm at Station I, with an overall site average of 3.87 cm. The contrast between the surface oxidized layer and underlying anoxic sediments at SE Loch were not as pronounced as they were at Bishop Point (Figure 5-20), again reflecting the increased bioturbational activity at SE Loch with greater resulting homogenization of the vertical sediment column.

#### *Infaunal Successional Stage*

Similar to the Bishop Point area, the SE Loch stations also had evidence of mature, deposit-feeding invertebrate assemblages at every fine-grained sediment location; as mentioned earlier, there was evidence of extensive bioturbation by larger deposit-feeding macrofauna, typical of a Stage III successional community. The only locations where deposit feeders were not present were at those hard bottom/cobble stations where prism penetration was prevented.

#### *Void Ratio*

The void ratio at SE Loch had a greater range than that found at Bishop Point, going from a minimum of zero to a maximum of 3.8% (Figure 5-21). However, a much greater proportion of the stations had void ratios in the 0-0.5% interval range compared with those at Bishop Point, even though there was more cross-sectional sediment area to analyze in this group of images (softer, more dilated sediments with greater penetration). Like the void ratios measured at Bishop Point, the values at SE Loch did not appear to correlate with any other measured SPI parameter (Table 5-3).

#### *Organism-Sediment Index*

The distribution of median OSI values is shown in Figure 5-22; only one location (Station F) had a median OSI value less than +6 (indicative of a recently disturbed habitat). A closer examination of the data from the individual replicate images (Appendix A) shows that two of the three images at Station F have OSI values below +6, either due to thin redox layers or an apparent lack of Stage III taxa. Other than this one anomalous location, the rest of the area surveyed revealed a benthic habitat experiencing low amounts of stress and supporting healthy benthic communities.

Table 5-3. Summary of Selected Average Measurements at SE Loch Stations.

<b>STATION NAME</b>	<b>Station Average Penetration (cm)</b>	<b>Station Average RPD (cm)</b>	<b>Station Average Boundary Roughness (cm)</b>	<b>Station Average Void Ratio</b>	<b>Station Maximum Void Depth (cm)</b>
SLA	15.35	2.08	2.48	0.14%	20.37
SLB	16.94	4.75	1.38	0.40%	15.64
SLC	8.59	3.02	1.98	1.09%	9.40
SLD	0.28	Indeterminate	2.76	0.00%	Indeterminate
SLE	12.88	3.26	4.34	1.60%	10.29
SLF	16.07	2.11	2.23	0.13%	6.48
SLG	19.73	4.84	0.86	0.49%	18.75
SLH	16.07	5.08	0.86	3.80%	14.89
SLI	5.11	6.62	1.35	1.60%	13.59
SLJ	3.12	3.31	2.70	0.05%	5.73
SLK	0.00	Indeterminate	Indeterminate	0.00%	Indeterminate
SLL	13.03	3.29	1.20	0.21%	11.21
SLM	17.68	5.18	0.73	0.61%	8.67
SLN	6.59	2.90	1.38	1.36%	11.51
	=====	=====	=====	=====	=====
<b>MEAN</b>	10.82	3.87	1.86	0.82%	12.21
<b>STD DEV</b>	6.74	1.40	1.03	1.04%	4.58
<b>CV</b>	62.4%	36.1%	55.0%	126.7%	37.5%

## Discussion

While the two areas surveyed in Pearl Harbor were both depositional environments that appeared quite healthy and robust from a standpoint of their benthic community development and structure, there were some noticeable distinctions between these two regions. From a physical dynamics standpoint, both areas appeared to be low kinetic regimes, with small-scale boundary roughness features caused mainly by biogenic activity. There was a higher sand fraction in the sediments at Bishop Point, with evidence of a thin surface layer (1 cm or less) of very fine sand at many of the stations; alternatively, the sediments at SE Loch, based on the saturation and albedo of the cross-sectional profiles, appeared to have a higher organic carbon content than those from Bishop Point. However, the most striking difference was in the geotechnical properties of the sediments at these two locations; the sediment shear strength at most of the SE Loch stations was substantially less than the majority of those stations surveyed at Bishop Point. We would predict that results from the sea flume would show a higher potential for seafloor erosion at locations in the SE Loch area (i.e., a much lower amount of energy would be required to achieve the critical shear stress at the SE Loch site). The low

sediment shear strength at SE Loch is mainly a function of the difference in macrofaunal composition at SE Loch with the resulting increased amount of bioturbation to greater depths in this location as compared to Bishop Point.

Stage III successional assemblages are the dominant community functional type at both areas surveyed (the key component for the relatively high OSI values found at each site; see Figure 5-14 and Figure 5-22); however, if classic benthic community studies had been done at these two areas, the diversity indices would be higher at the Bishop Point stations than those surveyed at SE Loch due to a higher species richness component. Figure 5-23 shows a closeup of the sediment-water interface at Station C in Bishop Point; while burrow openings of the larger, deposit feeding macrofauna can be seen, the high density of polychaete tubes associated with the burrow openings and projecting above the sediment-water interface indicate a diverse fauna utilizing different niche components for organic carbon sources. The presence of these surface tubicolous assemblages was much more common at the Bishop Point stations, and when they were present at SE Loch, it was in much lower densities than those at Bishop Point.

One particularly revealing aspect of this sediment profile imaging investigation came from the opportunity to do time-lapse imaging at one station in each of the areas surveyed; the results from these two deployments provided some tremendous insights into both the difference in bioturbation rates and associated processes occurring at these locations as well as the interpretation of different structures in the static “replicate images” taken as part of the regional survey. While the regular “regional survey” provided valuable information on the 3-dimensional spatial heterogeneity at the two sites, the time-lapse deployments provided insights for the first time on the fourth dimensional temporal heterogeneity -- the potential variation in reworking depths, reworking rates, and particle advection/ sediment transport that can occur at one location over a 24-hour period.

Some examples images from the time-lapse series taken at Bishop Point can be seen in Figure 5-24; while the large sub-surface feeding void in the middle of the cross-sectional profile (along with the appearance of the burrow structure in the lower right hand corner at the end of the recording) shows ample proof that larger, head-down deposit feeders were present in this area, the bulk of the bioturbational activity took place in the upper 12 cm. There was virtually no change in sub-surface void structure, no evidence of upward particle flux, and with the exception of the appearance of the burrow in the lower right-hand corner of the image, not much evidence of subsurface activity below 2 cm. The top 2 cm, on the other hand, were a virtual hotbed of movement from surface detritus and deposit feeders; repeated viewings of the separate time-lapse movie made of just the surface sediments at this location showed that the top 2 cm of sediment were constantly irrigated by both the feeding and burrowing activities of the dense assemblage of small, tubicolous polychaetes. A microprofile of porewater concentrations would most likely

show a fairly uniform concentration gradient throughout the top two cm at this location. Given the high density of animals and their high rate of activity, the porewater flux rate is most likely substantial, but the depth over which the flux was occurring was quite shallow, and the porewater and sediment volume being exchanged would not be as great as that at the SE Loch site.

The time-lapse profile at Station B in SE Loch showed quite dramatic changes in subsurface feeding void/burrow structure over time (Figure 5-25). The size of the three main sub-surface voids changed quite rapidly and frequently over the 24-hour recording period, and plumes of suspended sediment could periodically be seen being ejected from the main burrow on the left half of the image with their subsequent transport in the boundary layer region. It is quite obvious that a substantial volume of sediment is being reworked down to depths of 15 cm or more, with active movement of both porewater and sediment particles throughout the entire vertical interval. The paucity of tubicolous fauna at the sediment surface is easily explained by the dominating influence of the animals creating these burrows (Figure 5-26), both in terms of its bioturbation effects on sediment geotechnical properties and predation activities. The dramatic effects of crustaceans such as ghost shrimp and stomatopods on community structure and sediment properties have been documented in the past (e.g., Ott et al., 1976; Pemberton et al., 1976; Myers, 1979; Ziebis et al., 1996), and similar processes appear to be in action at much of the area in SE Loch. The large values for both prism penetration depth and Organism Sediment Indices (Figure 5-17 and Figure 5-22) were due largely to the influence of these organisms at many locations throughout the site.

Once the presence of these animals and their effects on sediment dilation was revealed from the time-lapse investigations, we were able to understand the apparent anomaly in the lower void ratio numbers from the SE Loch site as compared to Bishop Point. Because the ghost shrimp homogenize the sub-surface sediment so completely and rapidly (with voids/burrows quickly appearing and disappearing), the sediment is undergoing almost constant “roto-tilling” down to a depth of 15 cm or more. This causes this upper 20 cm of sediment to have extremely low shear strength and high water content, making it impossible for many of the sub-surface voids to remain structurally intact for any period of time. Even though the sediments in this site were subjected to more bioturbation and to a greater depth than those at Bishop Point, the information from the static profile images would have lead to the opposite conclusion because of the more consolidated nature of the sub-surface sediments at Bishop Point. The subsurface feeding voids at Bishop Point were better preserved and therefore more frequent and obvious in the sediment profile images from the spatial characterization survey. The surface sediments at SE Loch, on the other hand, had the appearance of fluidized deposits that are quite similar in appearance to recently deposited, hydraulically-dredged fine-grained sediments (uniform, homogeneous texture with high water-content); while the final appearance and geotechnical properties of both

kinds of sediments are quite similar, their origins are quite different (one is autochthonous sediments that are fluidized *in-situ* by the resident fauna, the other is allochthonous sediments that are fluidized mechanically and deposited from settling out through the water column). The difference in the time-lapse results at the two sites also helps explain why the investigators looking at groundwater flux in these two sites saw so much more “bioirrigation noise” in their measurements at SE Loch as compared with Bishop Point.

One of the main results from the PRISM project's first year field investigations in San Diego harbor was the spatial heterogeneity in community types and bioturbation depths documented by the SPI survey; while detailed investigations were carried out by other PRISM investigators at two selected locations within the site, the SPI results highlighted the limits to which those site-specific results could be extrapolated. Another key lesson learned was how important it is for the investigators to keep in mind the scale over which the individual measurements were made when integrating the final results from all the various studies. While the spatial variation in key parameters was once again documented in this survey, the time-lapse investigations at both Bishop Point and SE Loch demonstrated how *in-situ* temporal studies can reveal important insights both about the volume of sediment being reworked and the depths to which porewaters and particles are being advected that are not immediately obvious from measurements on static images (or isolated sediment cores). The changes in faunal activities that we documented are probably also influenced by both diurnal and tidal cycles, but further studies would be needed to confirm this. In any event, the type of biological community and density of organisms will have a profound influence on both sediment and porewater (and therefore contaminant) flux. The areas in Bishop Point that are similar to where the time-lapse recording was performed would have a relatively shallow “active layer” (2-4 cm), while those at SE Loch have an active layer that extends much deeper (15 cm or greater) and would have a much higher flux rate.

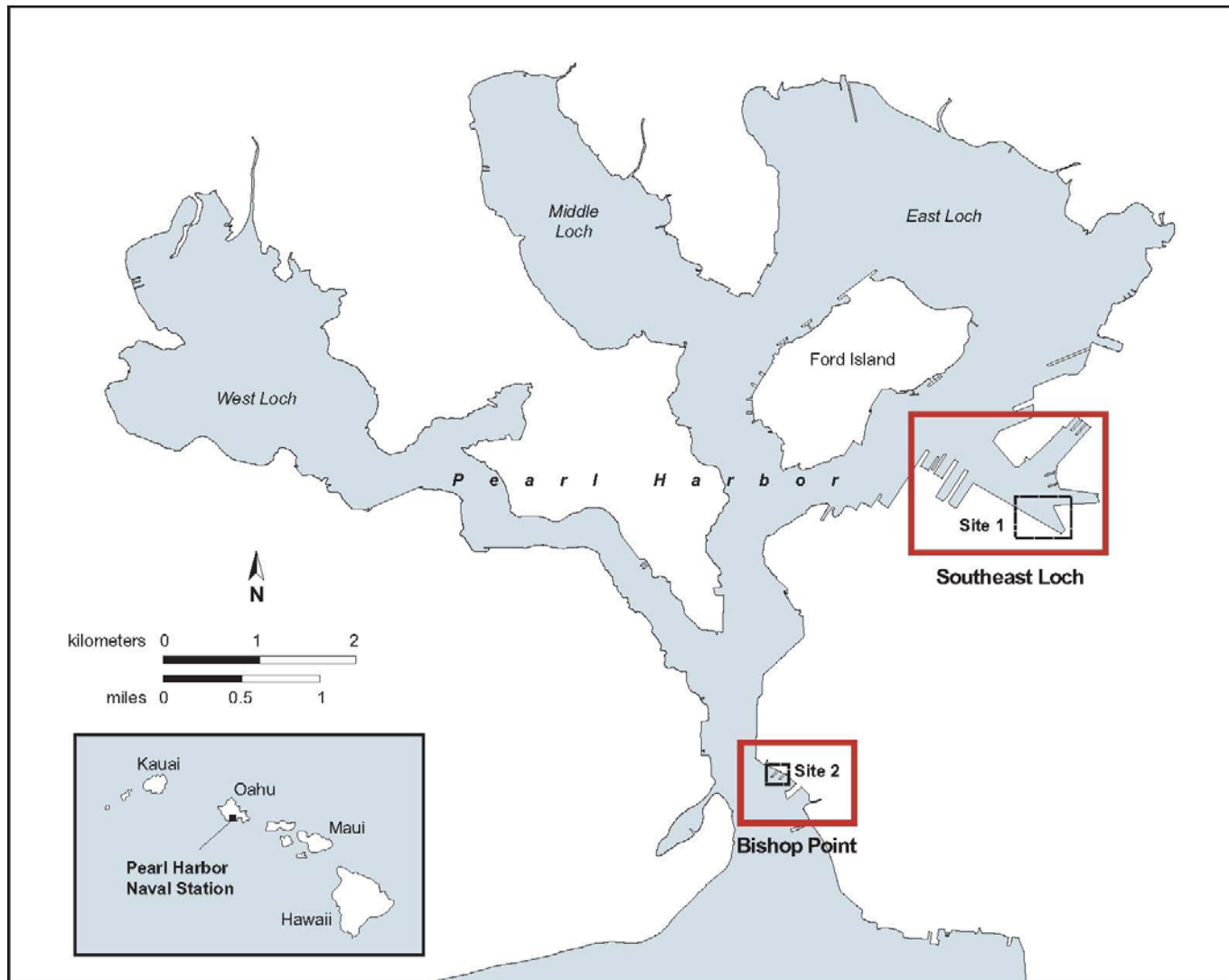


Figure 5-1. Location of PRISM study areas at the Pearl Harbor Naval Complex.





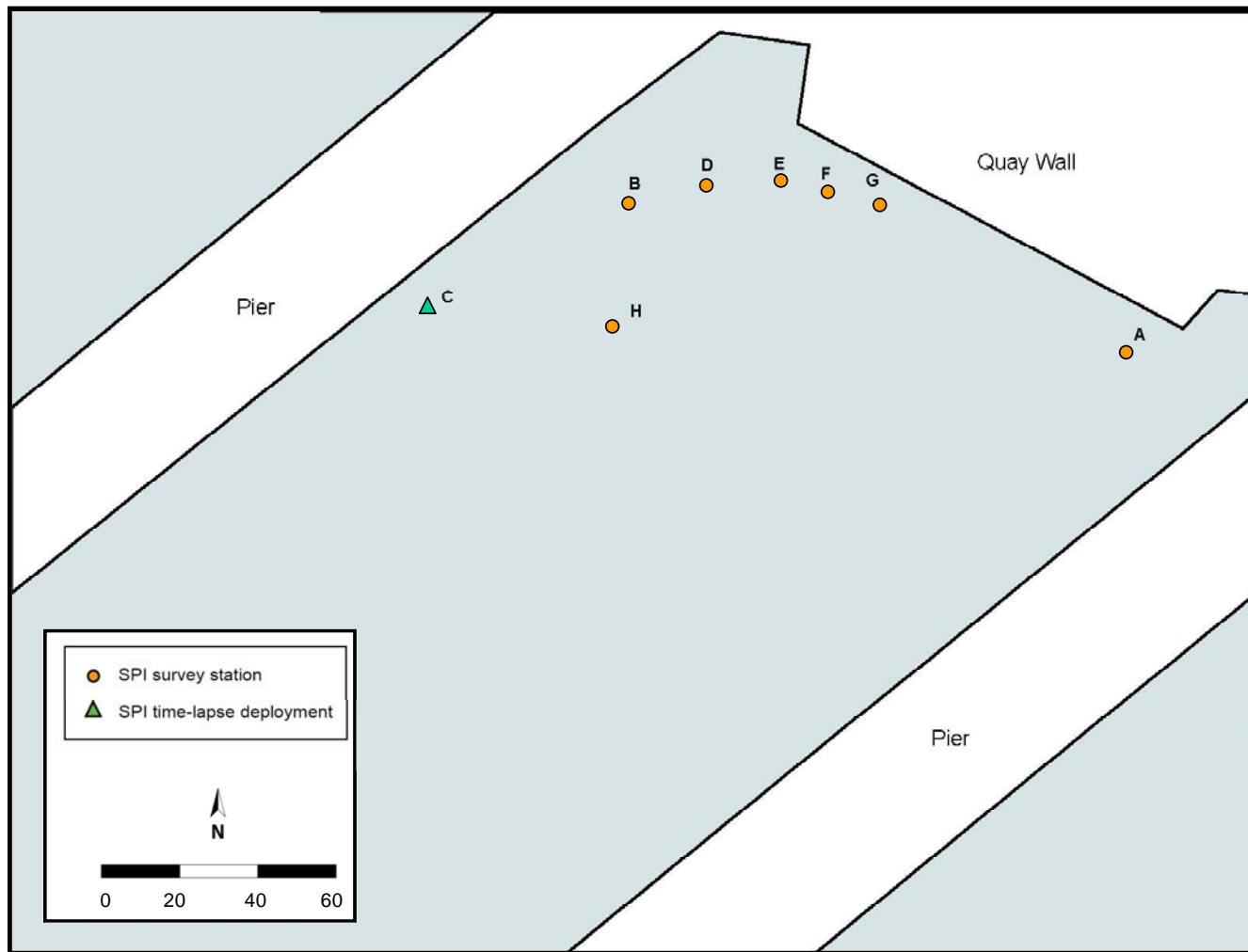


Figure 5-2. Location of SPI sampling stations surveyed at Bishop Point, Pearl Harbor, December, 2002.

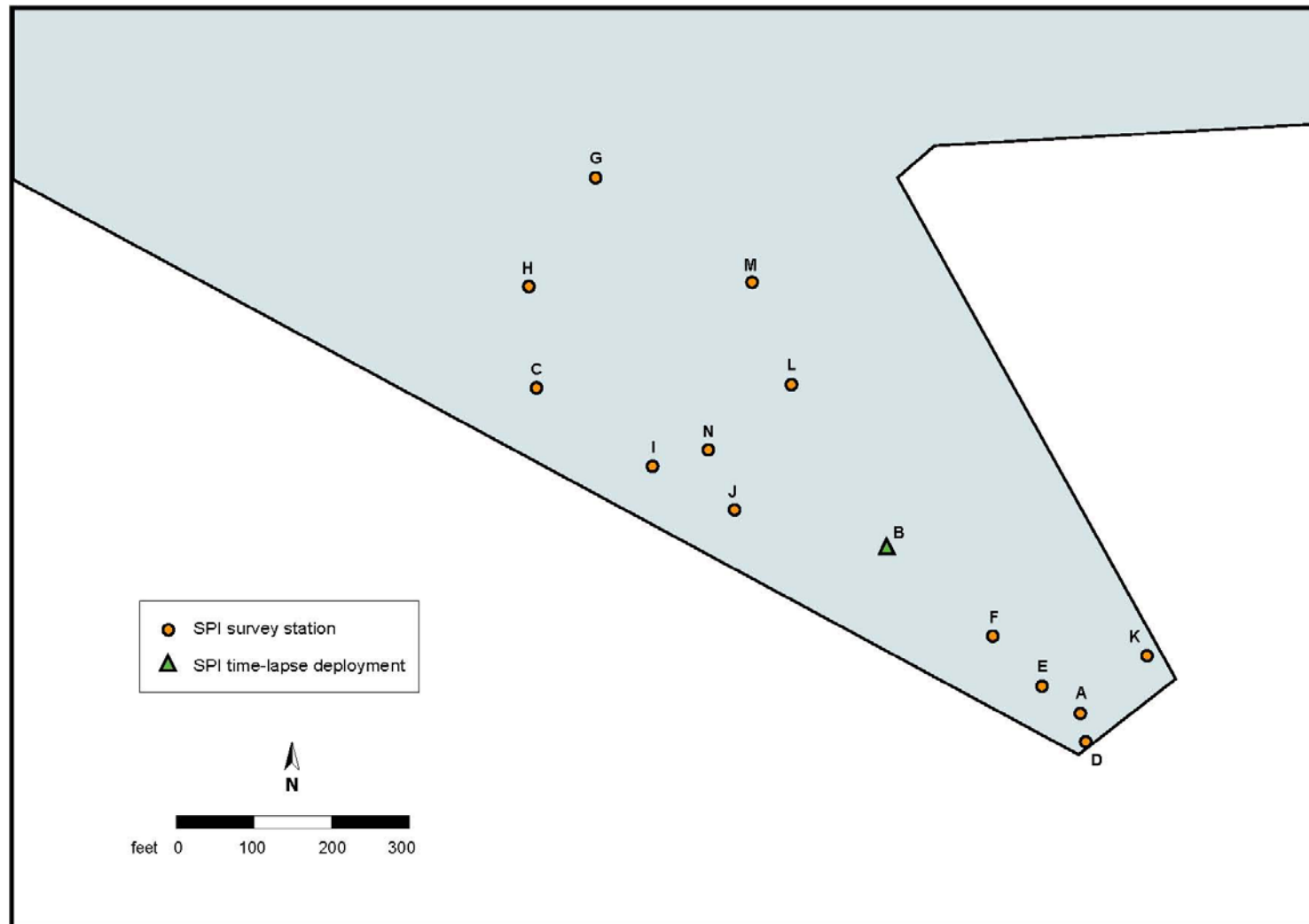


Figure 5-3. Location of SPI sampling stations surveyed at SE Loch, Pearl Harbor, December, 2002.



Figure 5-4. Sediment profile image from Station B at Bishop Point; a distinct accumulation of fine carbonate sands can be seen in the surface sediment (Scale: Width of image=15 cm).



Figure 5-5. One of the three replicate sediment profile images from Station A at Bishop point with organically enriched, very fine sand (Scale: Width of image = 15 cm).

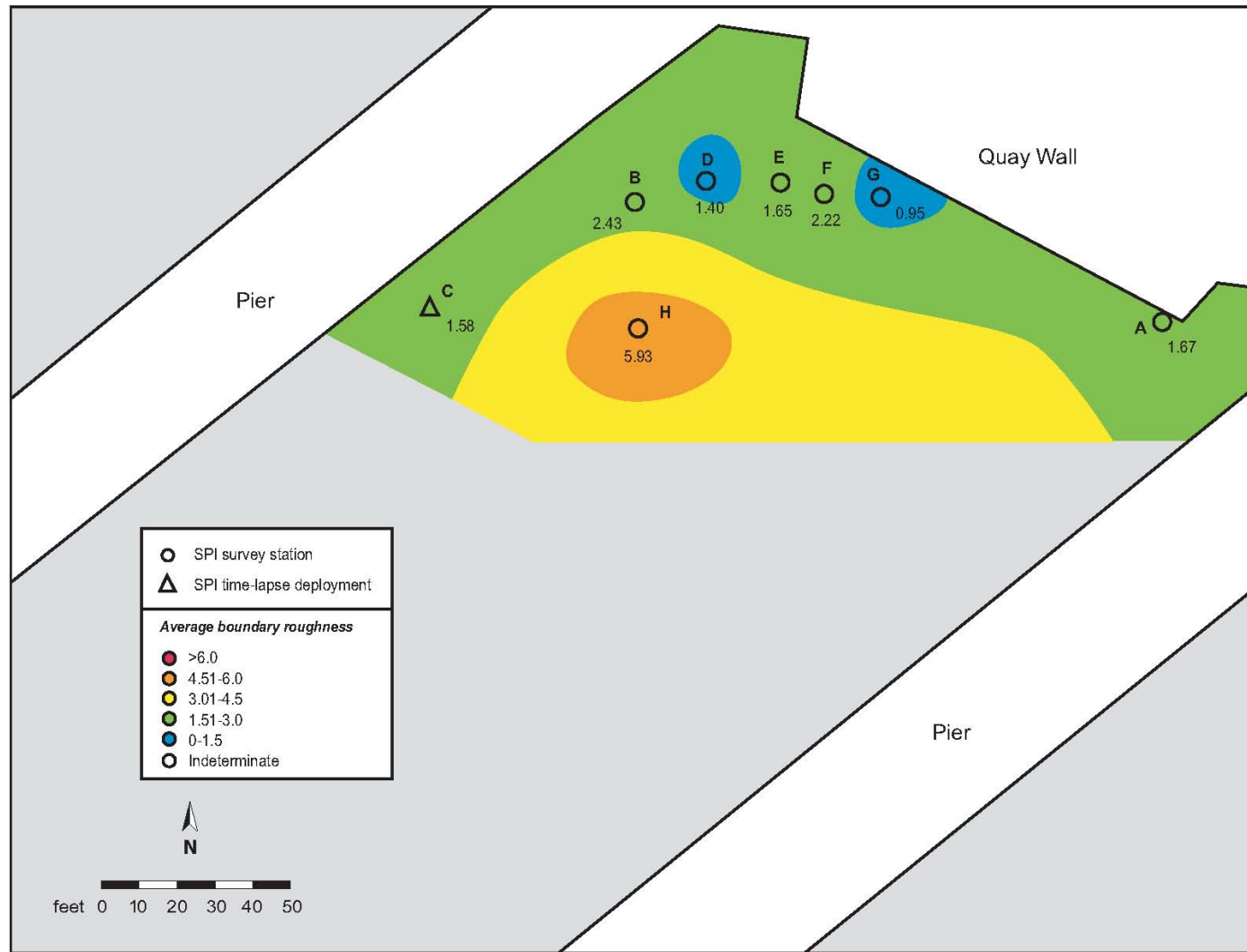


Figure 5-6. Distribution of average small-scale surface boundary roughness (cm) at Bishop Point.



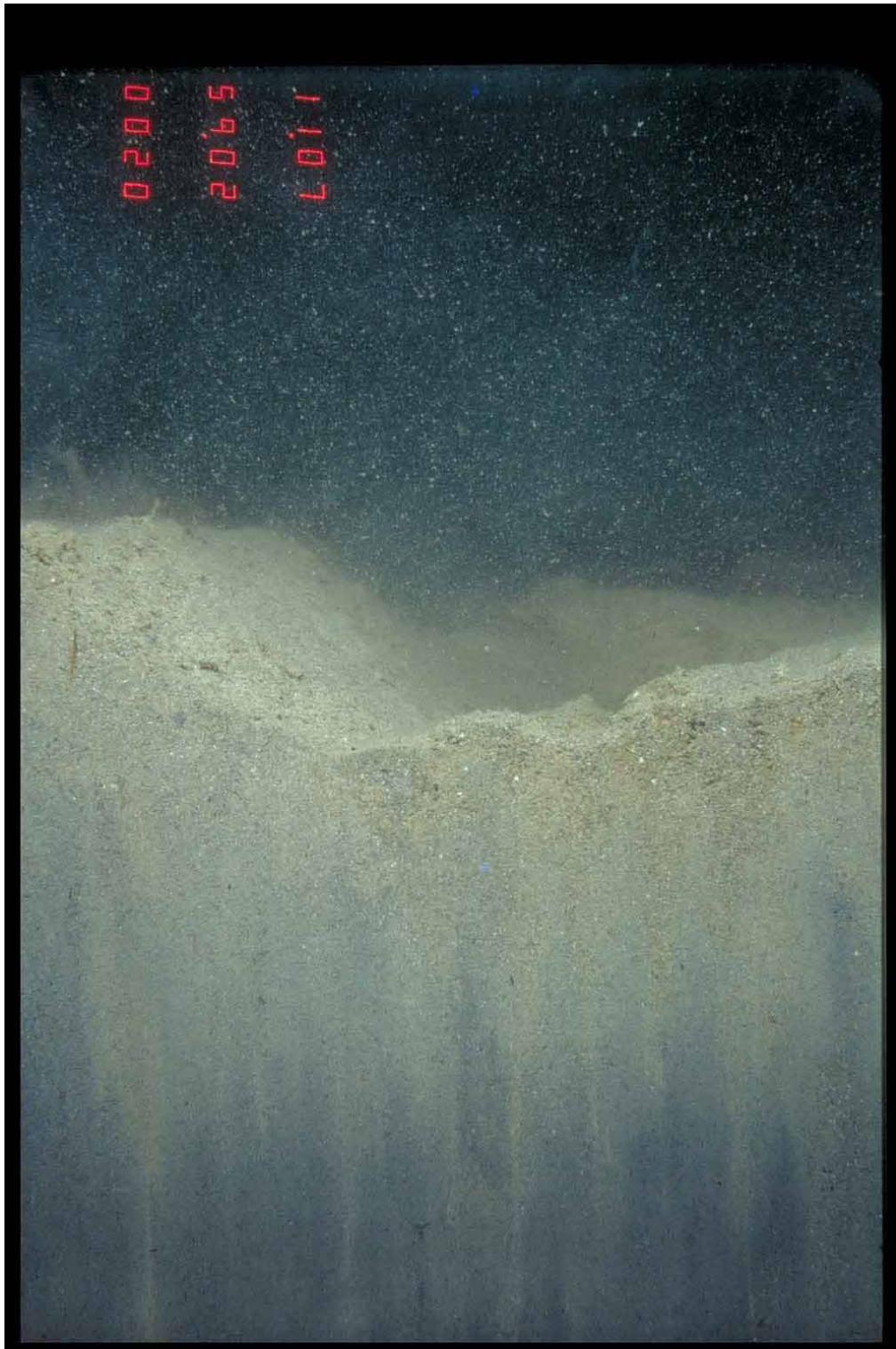


Figure 5-7. The prominent surface boundary roughness features seen in this image from Station B at Bishop Point are associated with the mound opening of burrowing shrimp. (Scale: Width of image = 15 cm).

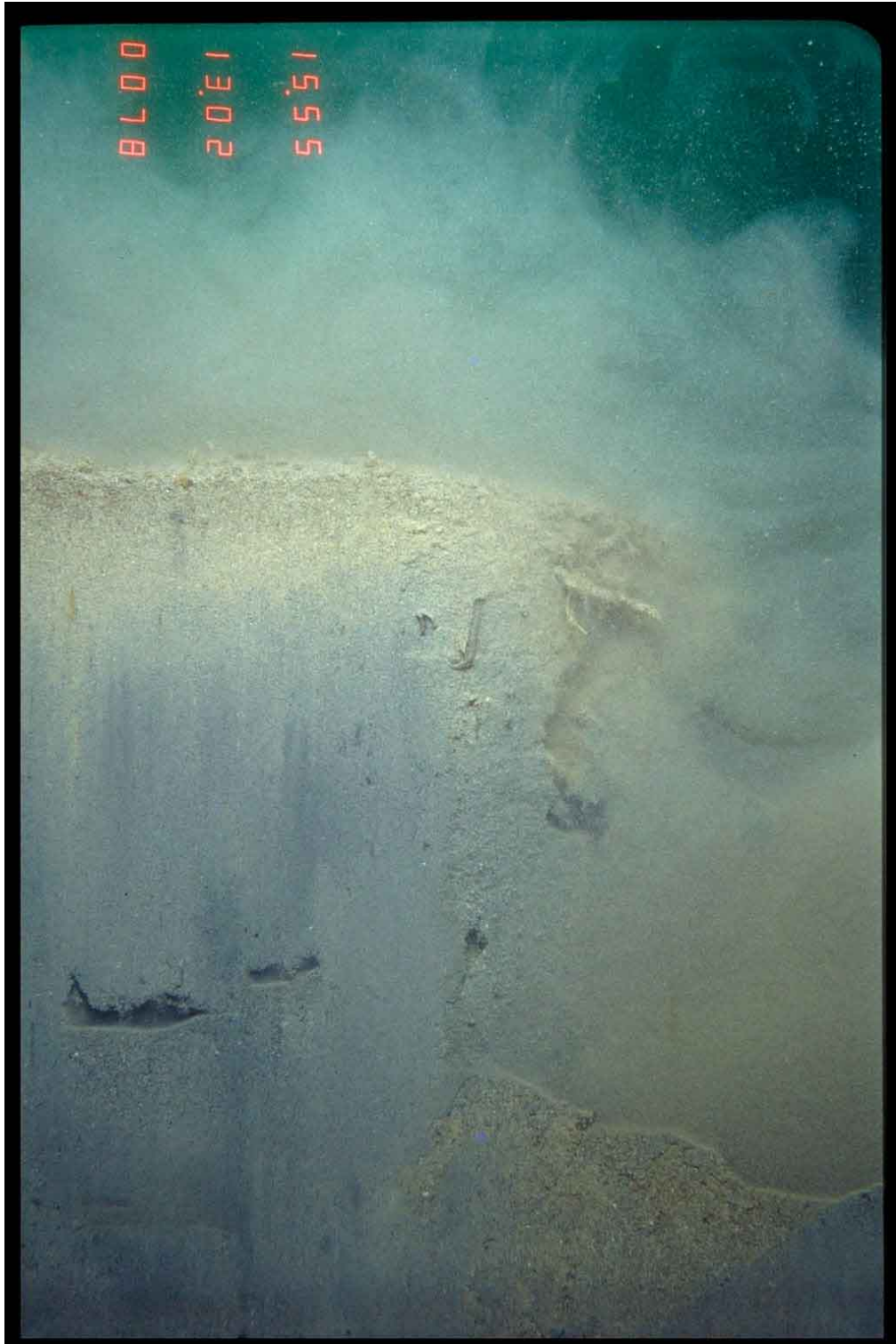


Figure 5-8. The large excavation in the right half of the image and associated high value for measured boundary roughness was caused by the camera prism during deployment for an earlier replicate image. (Scale: Width of image = 15 cm).





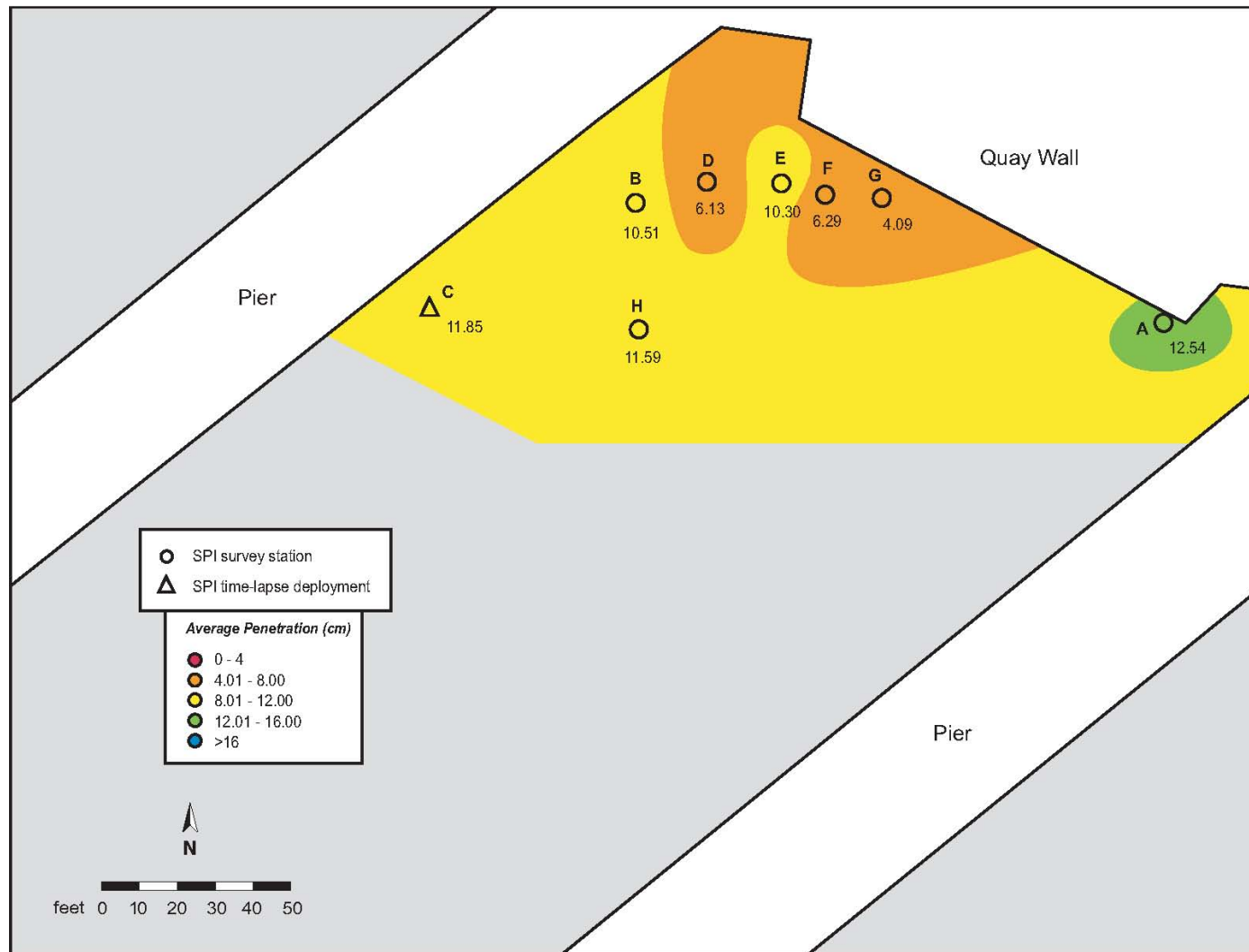


Figure 5-9. Distribution of average prism penetration depths (cm) at Bishop point.





Figure 5-10. Sediment profile images from Station A showing substantial burrow activity as well as evidence of organic loading from plant debris. (Scale: Width of each image = 15 cm).





Figure 5-11. Distribution of mean apparent RPD depth at Bishop Point.



Figure 5-12. Sediment profile image from Station C showing a fluidized bed with oxygen penetrating to the vertical limit of the camera prism due to ghost shrimp activities (Scale: Width of image = 15 cm).

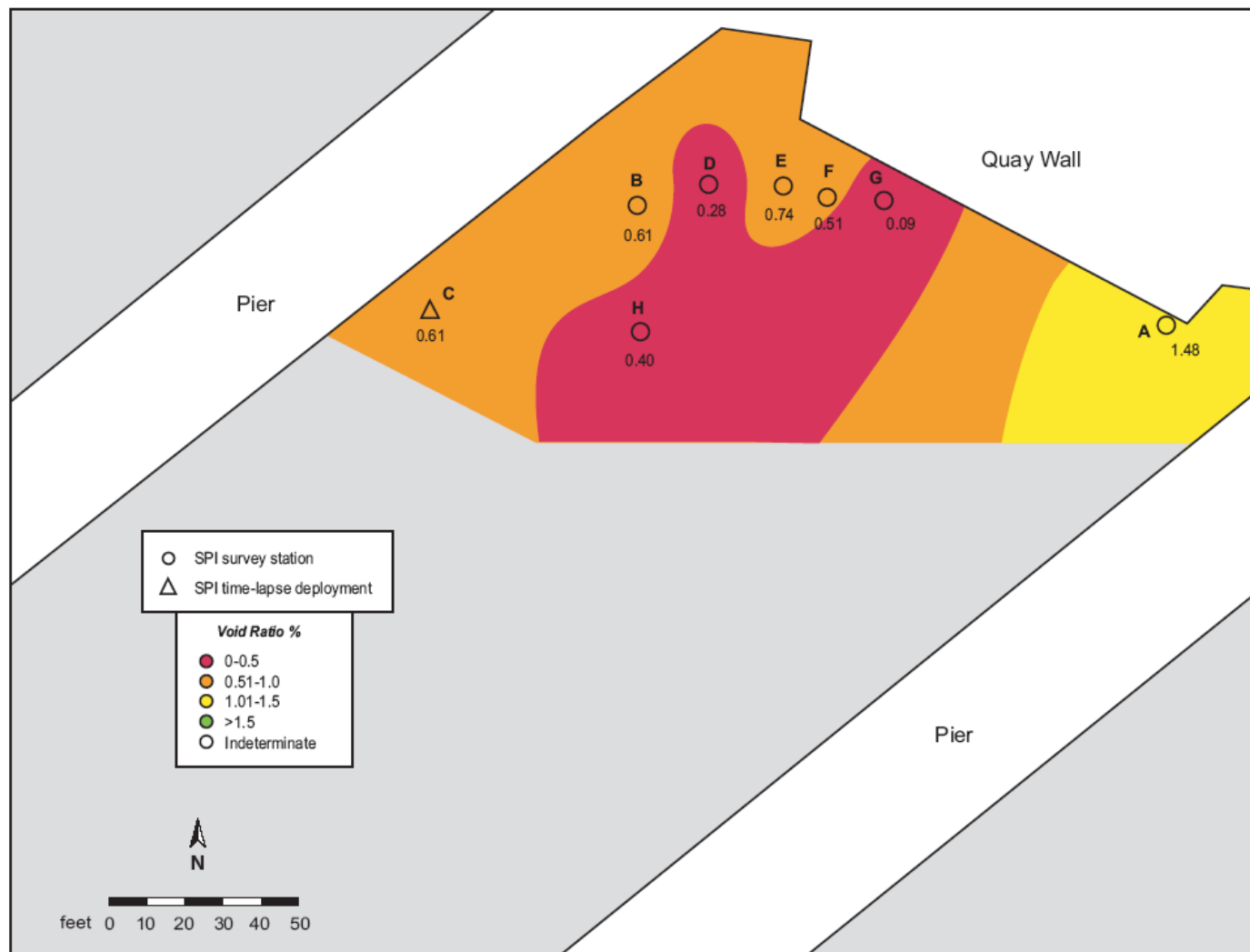


Figure 5-13. Distribution of average void ratio (%) at Bishop Point.



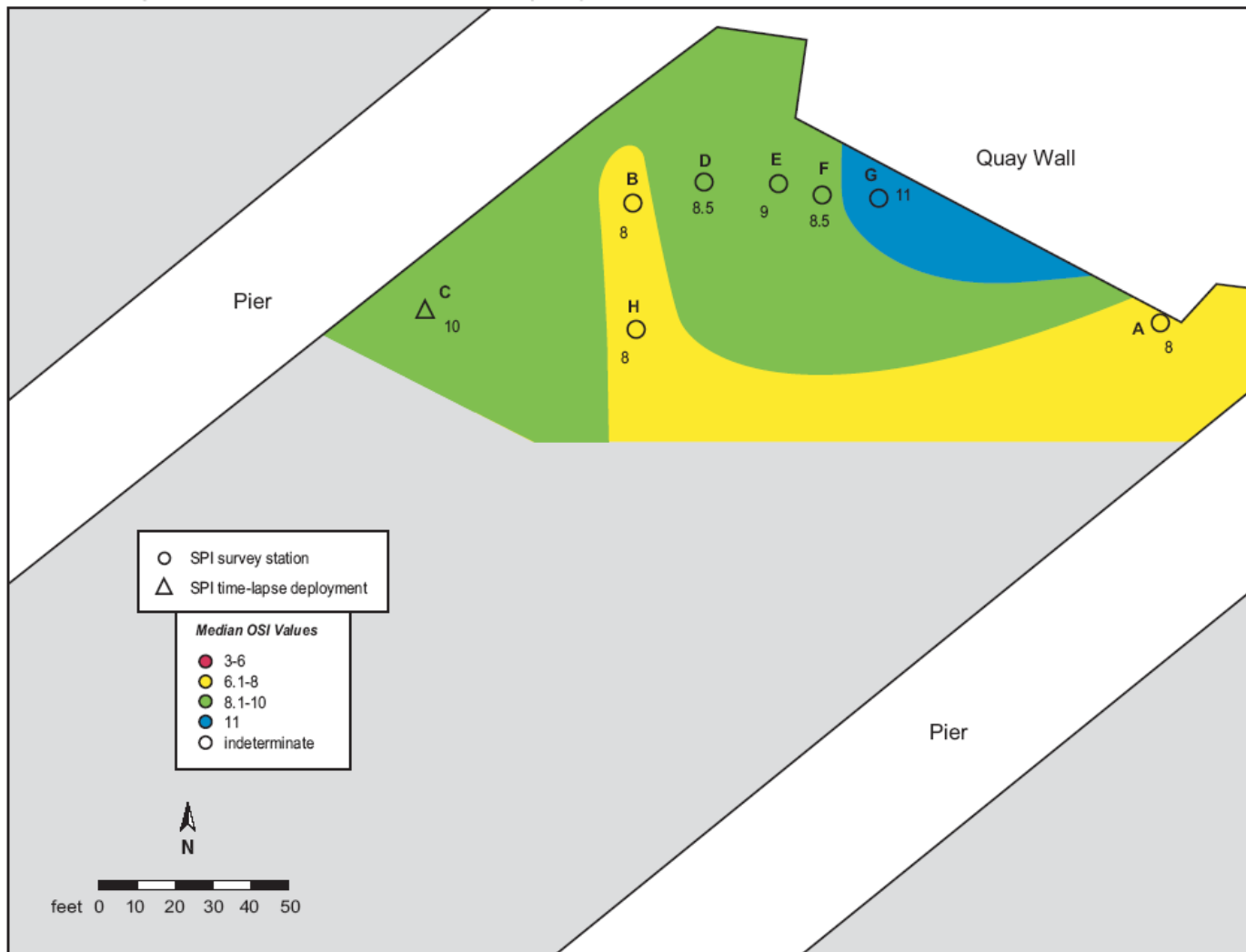


Figure 5-14. Distribution of median OSI values at Bishop Point.



Figure 5-15. Sediment profile images from SE Loch showing the two different sediment types found: a). The sediments at Station B were typical of the majority of locations; b) Station K had minimal penetration due to the hard cobble bottom (Scale: Width of images = 15 cm).

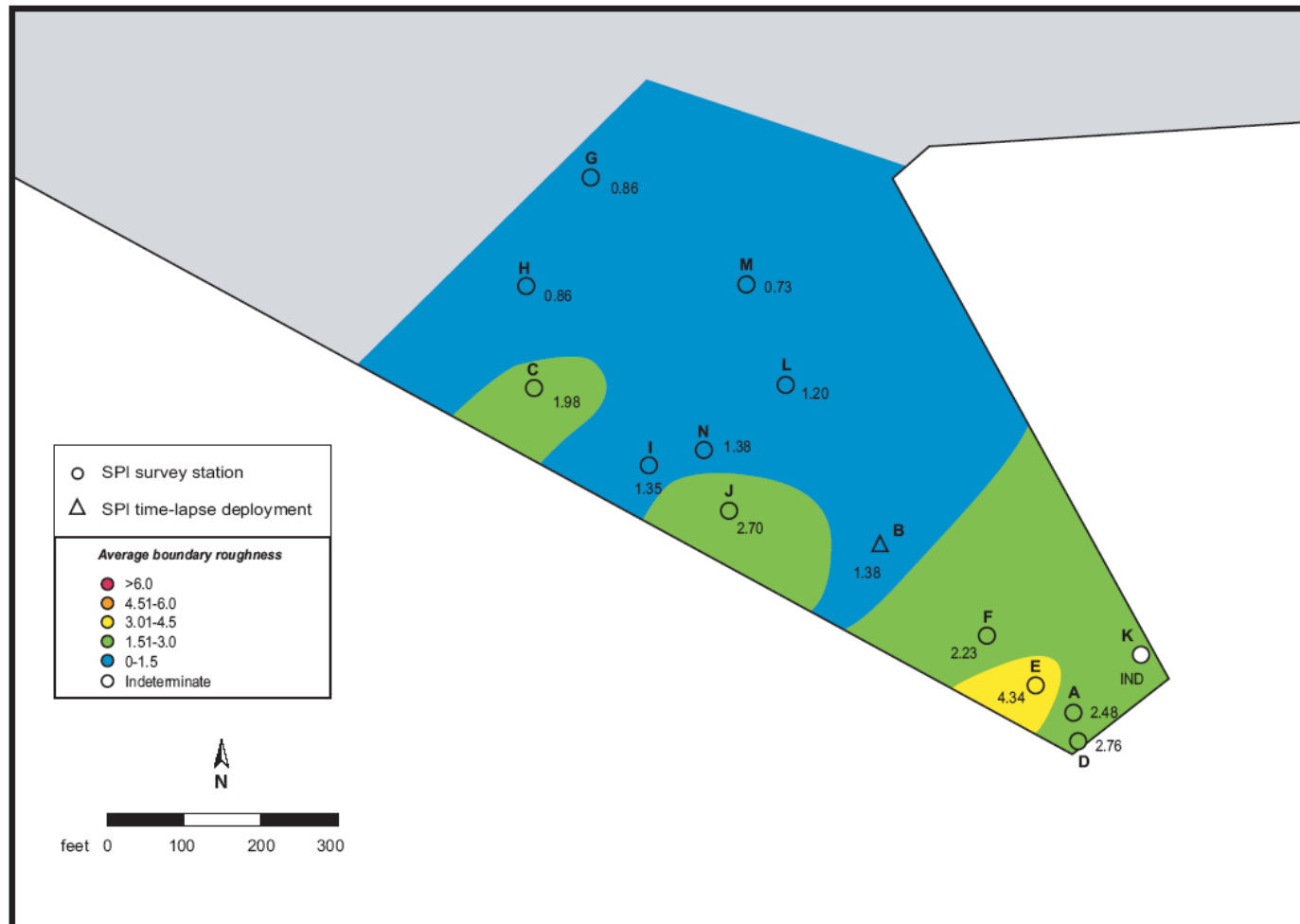


Figure 5-16. Distribution of average small-scale surface boundary roughness (cm) at SE Loch.

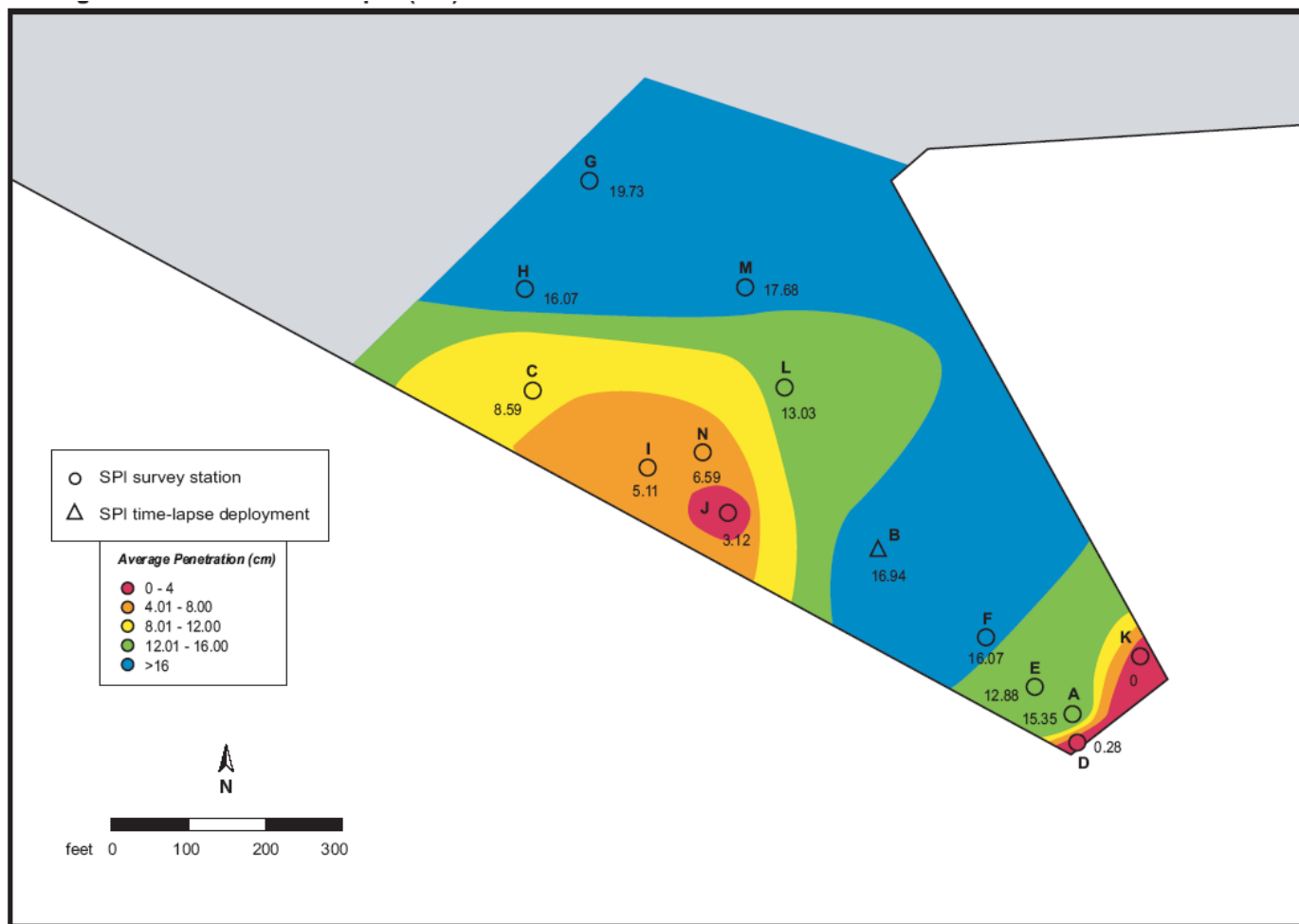


Figure 5-17. Distribution of average prism penetration depths (cm) at SE Loch.



Figure 5-18. Sediment profile image from Station H with an example of the extensive reworking the sediment has undergone from macrofaunal activity. (Scale: Width of image = 15 cm).

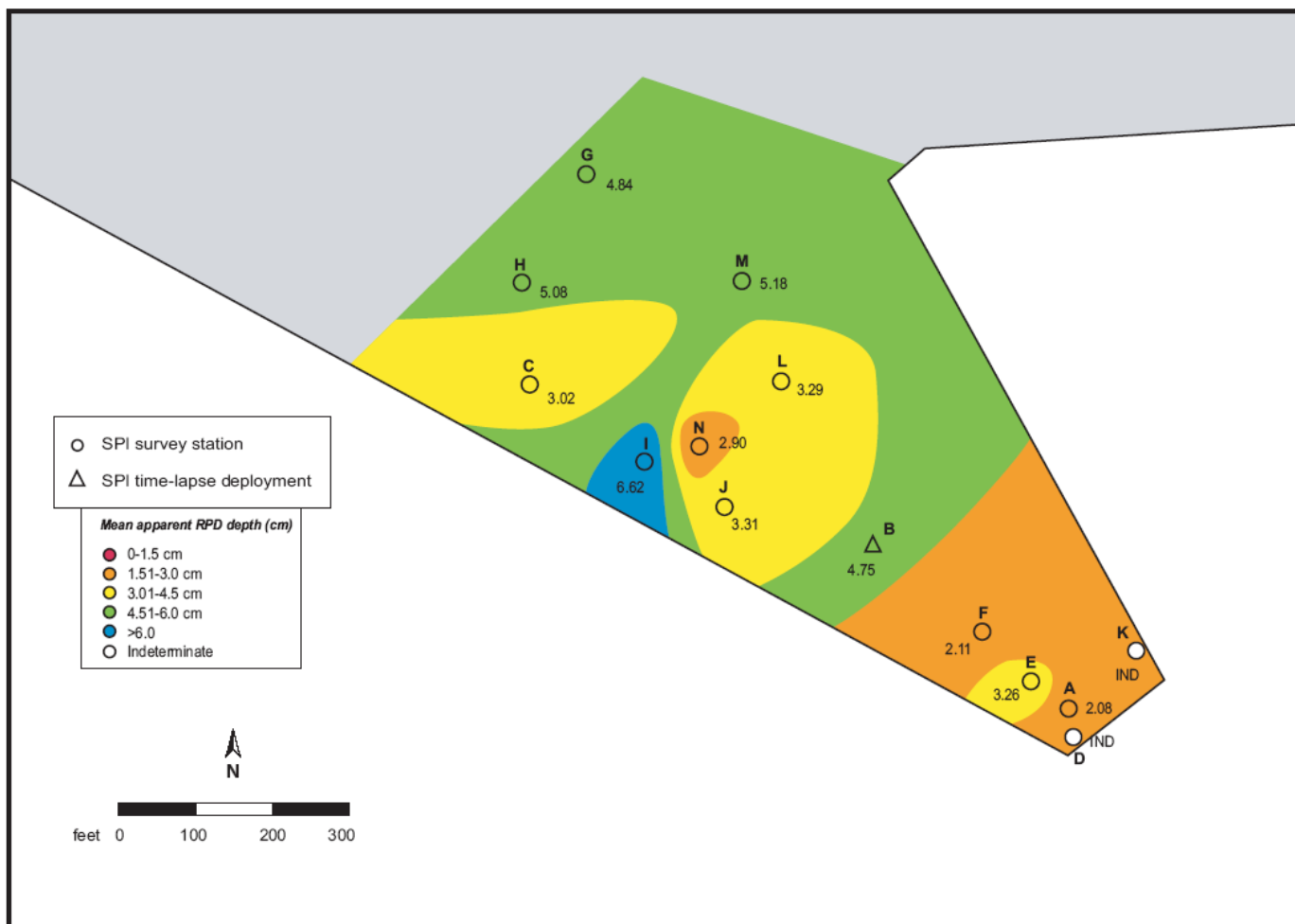


Figure 5-19. Distribution of mean apparent RPD depth (cm) at SE Loch.

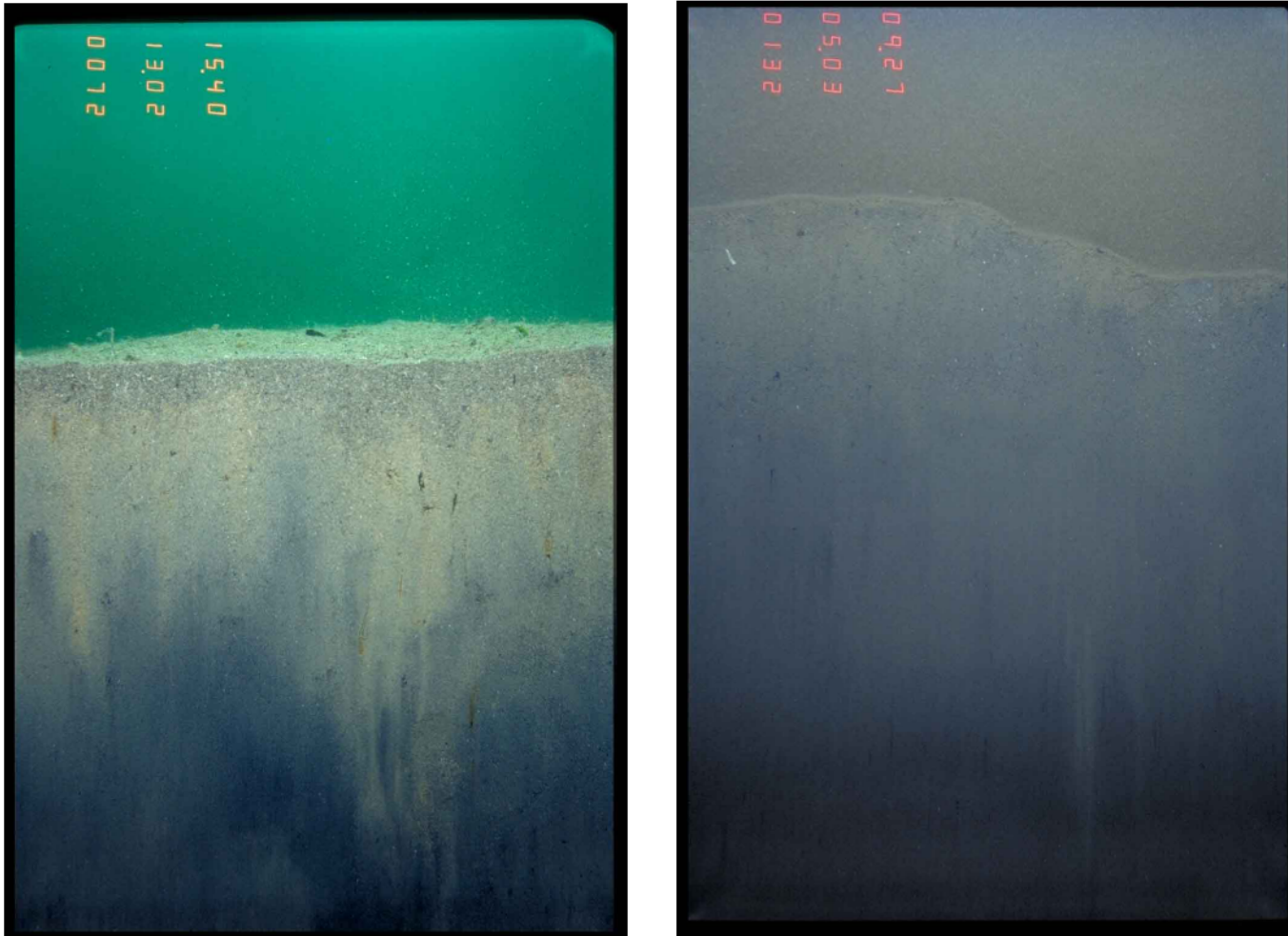


Figure 5-20. Note the difference in contrast between the surface oxidized layers and underlying anoxic sediments at the two locations surveyed (see text for explanation). a). Station C from Bishop Point. b). Station B from SE Loch. (Scale: Width of images = 15 cm).

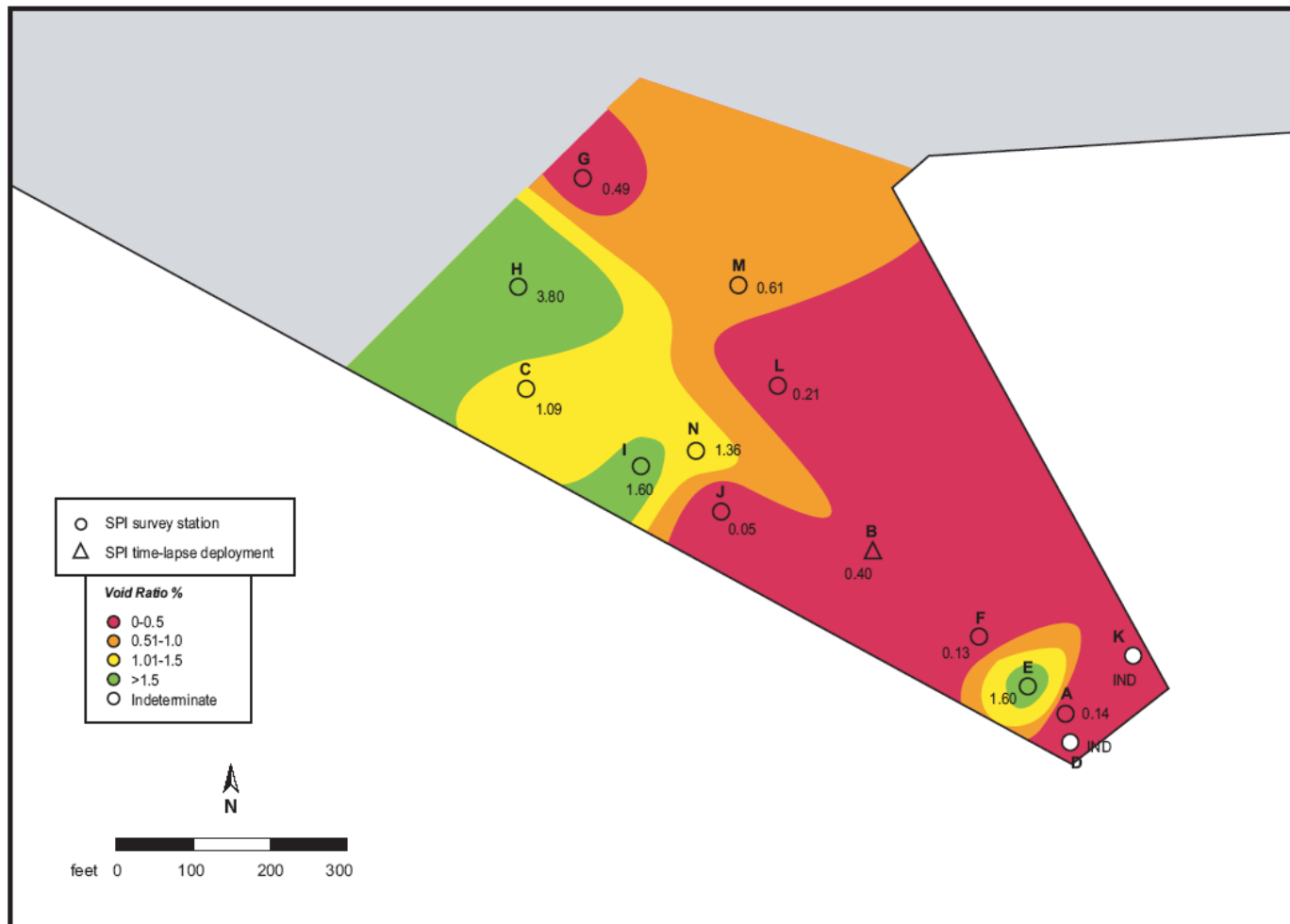


Figure 5-21. Distribution of average void ratio at SE Loch.



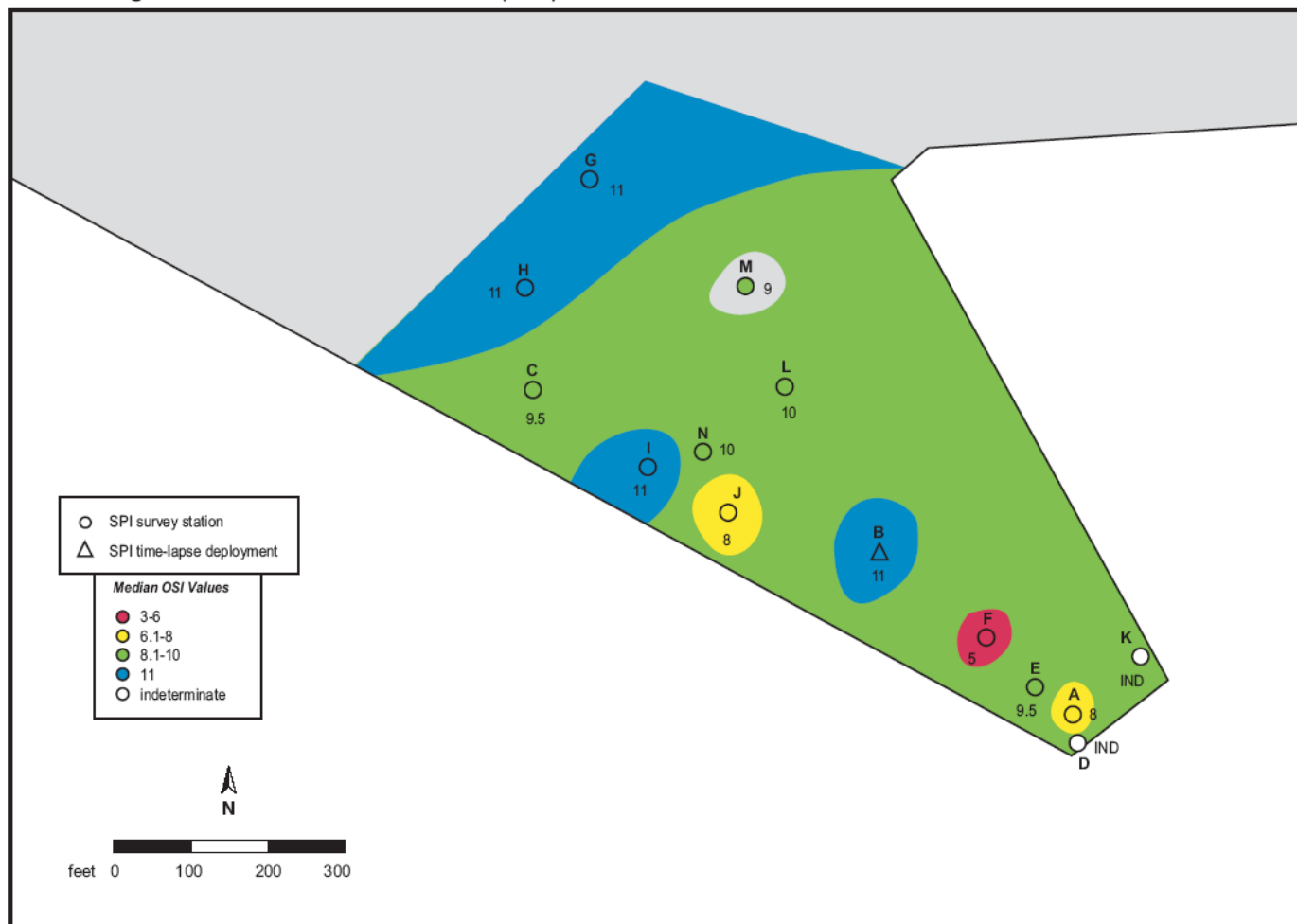


Figure 5-22. Distribution of median OSI values at SE Loch.



Figure 5-23. A close-up of the sediment surface at Station C from Bishop Point; notice the density of small polychaete tubes (arrows) at the sediment surface. (Scale: Width of image = 9 cm).

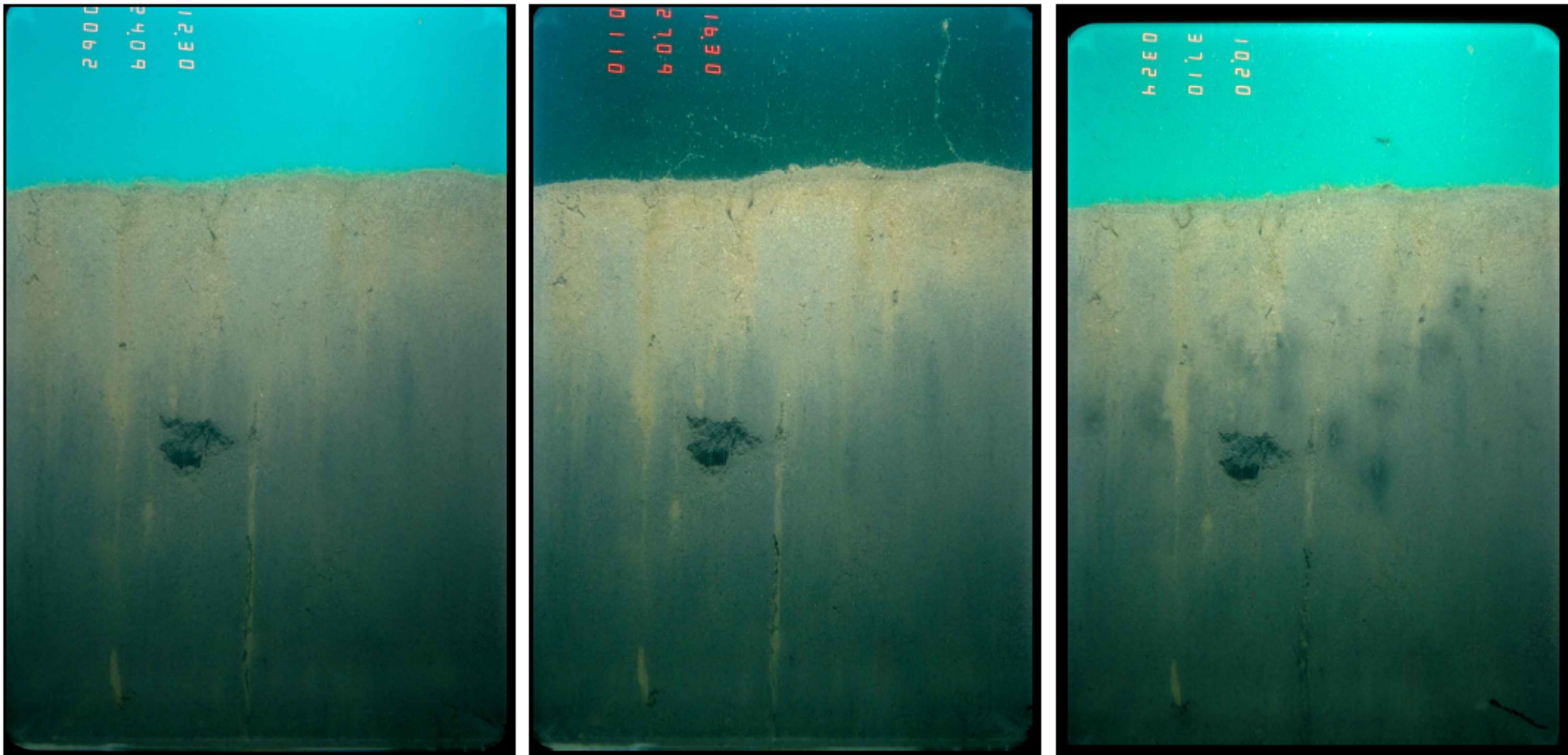


Figure 5-24. Sediment profile images from the start, middle, and end of the time lapse deployment at Bishop Point Station C. Note the appearance of the burrow at depth in the lower right corner (Scale: Width of images = 15 cm).

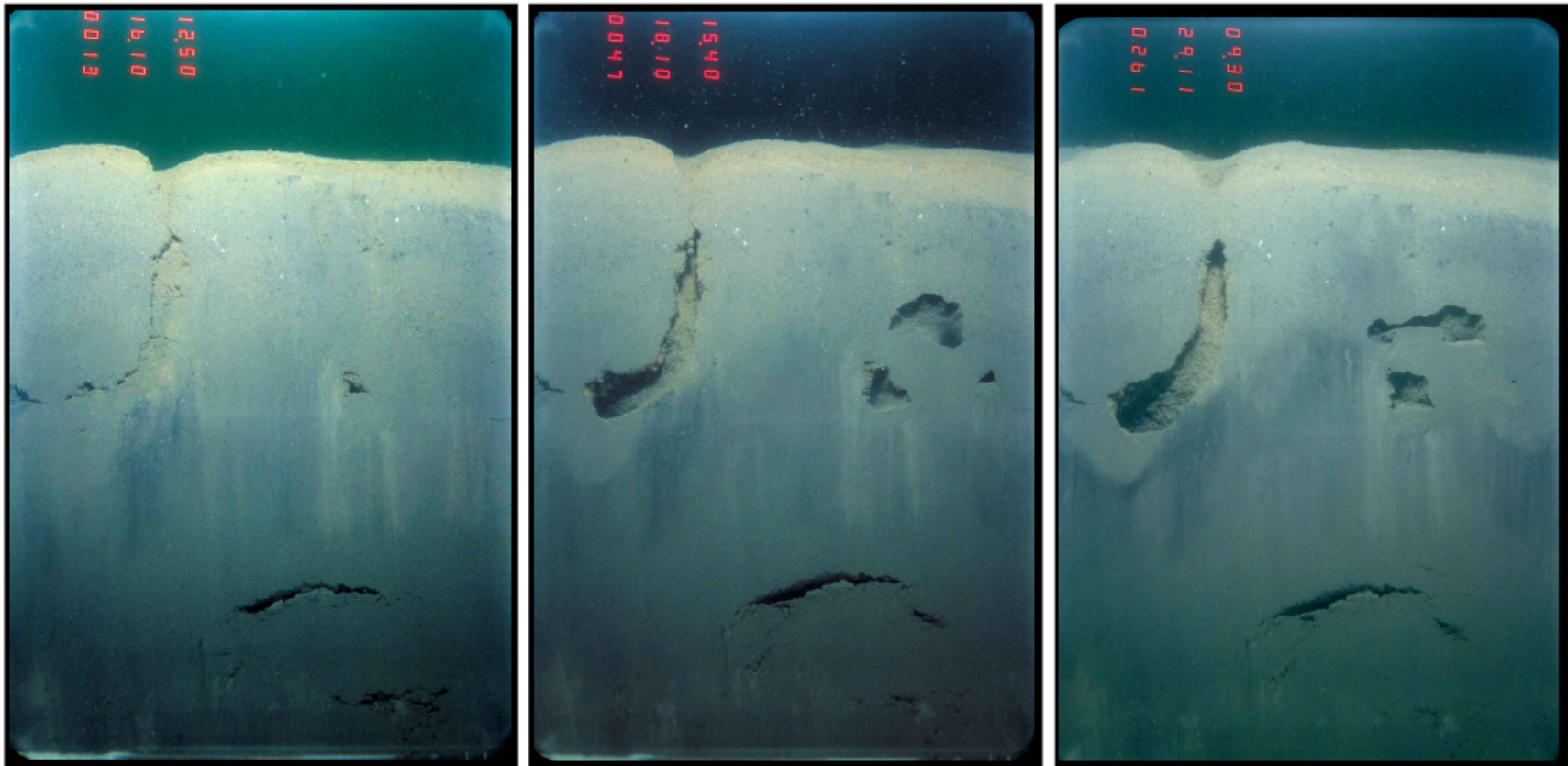


Figure 5-25. Sediment profile images from the start, middle, and end of the time lapse deployment at SE Loch Station B. Note the changes in size in the sub-surface feeding voids. (Scale: Width of images = 15 cm).





Figure 5-26. Sediment profile image from the SE Loch Station B time lapse series showing the main "culprit" responsible for the majority of the bioturbation occurring at this site. (Scale: Width of image = 15 cm).

## 5.2 IN-SITU QUANTIFICATION OF METAL AND PAH FLUXES

### Introduction

The objective of the PRISM program is to provide an understanding of the relative importance of critical contaminant transport pathways for in-place sediments in the risk, fate and management of contaminated sediments via: 1) An integrated suite of measurement techniques to characterize and quantify important transport pathways for in-place sediments, 2) A corresponding set of indices that quantify the transport phenomenon on a common dimensional scale and 3) Field scale evaluation of the effectiveness of the measurement tools and the importance of quantified transport pathways.

As a component of the Pathway Ranking for In-place Sediment Management project (PRISM), six 70-hour deployments using Benthic Flux Sampling Devices (BFSD 1 and BFSD 2; see Figure 5-27) were conducted at the Pearl Harbor PRISM sites in Southeast Loch and Bishop Point.. The goal of the BFSD deployments was to quantify the magnitude and variability of the diffusive flux pathway within the PRISM conceptual model.

The study sites were located at Southeast Loch and Bishop Point. Southeast Loch was expected to be impacted by potential groundwater intrusion, and perhaps introduction of COPCs via some old tanks. Bishop Point was the site with the highest current velocities, and thus it was expected that resuspension, if important, would be most likely at this site. Thus, these sites provided the greatest probability of detectable signals and impacts by a range of processes.



Figure 5-27. View from quay wall looking northwest into the Bishop Point study area.

## **Methods**

### **Site Selection**

Two survey strata were selected on the basis of previous sampling in Pearl Harbor. The strata were selected to represent a potential range of conditions that could lead to differences in dominant pathways of contaminant migration and fate. The sampling design specified three sampling stations within each strata. The stations were designated as SEL (A,B,C) for the Southeast Loch strata (corresponding to sub-strata 1fz from the IR study), and BP (A,B,C) for the Bishop Point strata (corresponding to sub-strata 2iy from the RI study). The SEL strata extended from the innermost reach of Southeast Loch to tip of Merry Point, and the three stations were distributed along this reach from SEL-A at the inner, to SEL-C at the outer. The BP strata extended primarily between the two main piers from the quay wall to the pier heads at the Bishop Point. At each station within a strata, a BFSD deployment was made, including two standard deployments and one in which we attempted to determine bioinhibited flux rates (Figure 5-28).

### **Traditional flux measurements**

Diffusive fluxes were quantified through the direct measurement of benthic fluxes utilizing the Navy's existing Benthic Flux Sampling Devices (BFSD1 and BFSD2; Figure 5-29). The BFSD consists of an open-bottomed chamber mounted in a tripod-shaped framework with associated sampling gear, sensors, control system, power supply, and deployment/retrieval equipment. The chamber is a bottomless box approximately 40-cm square by 25-cm tall that isolates 37.5 l of seawater. As samples are drawn from this volume, bottom water is allowed to replace it via a length of 4-mm Teflon tubing. The volume was chosen to allow for a maximum overall dilution of 10% due to sampling withdrawal and subsequent replacement of twelve samples of 250-ml each. The chamber is constructed of clear polycarbonate to avoid disrupting any exchanges that may be biologically driven and potentially light sensitive. The bottom of the chamber forms a knife edge with a flange circling it 5 cm above the base providing a positive seal between the box and the sediment. The data logger collects data from a suite of sensors mounted in a flow-through loop on the lid of the chamber including temperature, oxygen, pH, and salinity. The control system is an integrated part of the data logger and performs several functions including control of lid closure, activation of flow-through/mixing pump, opening of sampling valves, and chamber oxygen regulation. The method has been utilized for a range of analytes including inorganic constituents such as oxygen and nutrients (McCaffrey et al., 1980; Berelson et al., 1986), trace metals (Ciceri et al., 1992, Leather et al., 1995), and is currently being adapted for organic contaminants under support from the ESTCP program.

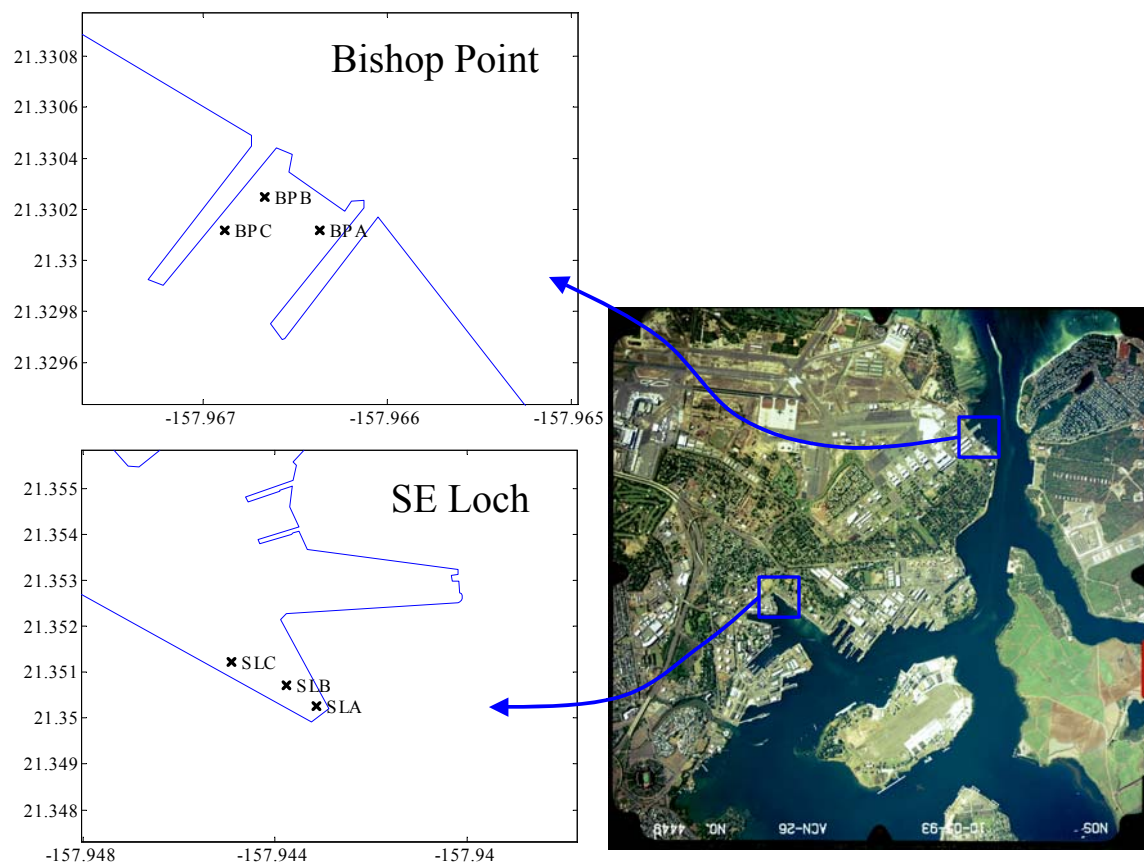


Figure 5-28. Map of the Pearl Harbor sampling areas, showing deployment locations for the flux study.



Figure 5-29. The Benthic Flux Sampling Device (BFSD2) used to sample sediment fluxes at Pearl Harbor.



### **Bioinhibited flux measurements**

While the BFSD is capable of measuring diffusive fluxes of COPCs independently of most advectively-driven fluxes (which will be measured with seep meters), the BFSD as currently used cannot separate fluxes driven by diffusion from fluxes across the sediment-water interface driven by bioirrigation. However, these fundamentally different flux drivers may affect the way contaminant pathways may be managed. Dryssen et al (1984) observed that, when oxygen was allowed to deplete in a BFSD chamber, the flux rate of Si dropped significantly, suggesting that the flux from biological irrigation had ceased or significantly decreased due to oxygen limitations. To separate flux by these two mechanisms, bioinhibited flux were measured in the BFSD. In these experiments, we attempted to inhibit biological activity allowing oxygen to deplete in the chamber. Since these activities may change the diffusive properties of metals and/or organics, we also evaluated fluxes of Si, and then proposed that the COPC flux be calculated based upon the surrogate:COPC ratio in the biologically active flux measurements.

### **Pre-Survey Preparation**

Prior to deployments, the BFSDs were cleaned and prepared using previously standardized procedures (Chadwick and Stanley, 1993; Hampton and Chadwick, 1999). Decontamination involves soaking and/or rinsing all surfaces contacting seawater samples in a series of fluids beginning with tap water, then de-ionized water, then a special detergent ("RBS"), then de-ionized water, then nitric acid, then 18 meg-ohm de-ionized water and finally filtered air. In addition, components of BFSD1 were subjected to a final rinse with methanol to remove any residual organic contaminants. The collection bottles for BFSD2 were disassembled and all component parts were soaked for a minimum of four hours in each fluid. A 25% concentration of ultra-pure nitric acid was used to soak Teflon™ parts (bottles, lids, and sensor chamber) and a 10% concentration is used for all other parts (including acid-sensitive polycarbonate filter bodies). Glass sample bottles for BFSD1 and BFSD2 were purchased pre-cleaned. For both chambers, the collection chamber, lid, diffuser, circulation pump, tubes and fittings were physically scrubbed and rinsed in place with non-metallic brushes. All decontaminated surfaces were dried, reassembled or otherwise sealed to isolate them from ambient, air-borne contaminants.

### **Deployment**

Aboard the deployment vessel, after loading and connecting various equipment (laptop computer, TV monitor and light, cabling) a standard pre-deployment checklist was followed (Hampton and Chadwick, 1999). Once moored at the site with the GPS location logged, the BFSD was lowered to within 2 feet of the bottom and a 15-minute test was started to stabilize the flow-through sensors and to measure the ambient dissolved oxygen level. The ambient dissolved oxygen level is used to establish system control limits for maintaining a narrow range of dissolved oxygen in the collection chamber during the 70-hour test, as well as for assessment of sediment oxygen uptake rates. The BFSD was then allowed to free-fall to the bottom and insert its collection chamber into the sediment. The landing and insertion were monitored using a video camera. The video camera, aided by a floodlight, also allowed a limited assessment of the site prior to initiating the 70-hour test. After starting the test, it also allowed confirmation of lid closure prior to complete detachment of lanyards and connections for autonomous operation. Following

detachment of the lifting and telemetry cables, the BFSD was left in its autonomous operation mode for the following 3 days.

**Retrieval**

Retrieval of the BFSD after the deployment was made using the onboard recovery system. Once the BFSD was washed down and on deck, the sample bottles were removed for processing using EPA handling and chain of custody procedures. The samples were returned to the shoreside laboratory for splits (nutrients, metals and organics). Silica measurements were made at the shoreside laboratory using a field portable, Hach model DR2010 Instrument. The metals samples were packaged and shipped to Battelle Marine Sciences Laboratory for analysis of the metals selected for evaluation (

Table 5-4). Samples for analysis of organics were shipped to the laboratory of Arthur D. Little (

Table 5-4).

**Data Analysis**

Following chemical analysis, flux rates were determined using the standard Microsoft Excel spreadsheet template developed during CALEPA certification (Hampton and Chadwick, 1999). The spreadsheet calculates flux rates using the time-series concentrations from each bottle and adjusting for dilution. The flux rates are then evaluated statistically to determine if the fluxes are significantly different from flux chamber blanks. Results of this analysis are described below.

Table 5-4. Target analytes and analytical methods for the flux study.

<b>Metals - U.S. EPA 1631,1638 &amp; 1640</b>	
Aluminum	Manganese
Arsenic	Mercury
Cadmium	Nickel
Chromium	Selenium
Copper	Silver
Iron	Tin
Lead	Zinc
<b>Polynuclear Aromatic Hydrocarbons - U.S. EPA SW-846 8270 modified using SIM</b>	
Naphthalene	Dibenzothiophene
C1-Naphthalenes	C1-Dibenzothiophenes
C2-Naphthalenes	C2-Dibenzothiophenes
C3-Naphthalenes	C3-Dibenzothiophenes
C4-Naphthalenes	Fluoranthene
2-Methylnaphthalene	Pyrene
1-Methylnaphthalene	C1-Fluoranthenes/Pyrenes
2,6-Dimethylnaphthalene	C2-Fluoranthenes/Pyrenes
2,3,5-Trimethylnaphthalene	C3-Fluoranthenes/Pyrenes
Biphenyl	Benzo(a)anthracene
Acenaphthylene	Chrysene
Acenaphthene	C1-Chrysenes
Fluorene	C2-Chrysenes
C1-Fluorenes	C3-Chrysenes
C2-Fluorenes	C4-Chrysenes
C3-Fluorenes	Benzo(b)fluoranthene
Phenanthrene	Benzo(k)fluoranthene
Anthracene	Benzo(e)pyrene
C1-Phenanthrenes/Anthracenes	Benzo(a)pyrene
C2-Phenanthrenes/Anthracenes	Perylene
C3-Phenanthrenes/Anthracenes	Indeno(1,2,3-c,d)pyrene
C4-Phenanthrenes/Anthracenes	Dibenz(a,h)anthracene
1-Methylphenanthrene	Benzo(g,h,i)perylene

## Results

### Performance Indicators

Several methods were used to evaluate system performance of the BFSDs during and after the demonstrations. To assure a proper seal of the chamber, the deployment was monitored by diver and with an underwater video camera, and silica, pH, Mn and oxygen levels within the chamber were monitored for expected trends. Landing and insertion monitored by diver and with the video indicated a good seals. After starting the test, the video camera also confirmed lid closure of the chambers.

A number of geochemical parameters are also useful in evaluating the general performance of the system, including silica, pH, Mn and oxygen levels within the chamber. Experience has shown that proper chamber seal and performance results in a positive flux for silica and manganese, a negative flux for oxygen, and a decreasing trend in pH (Hampton and Chadwick, 1999). Results for these parameters for the six deployments are summarized in Table 5-5 below. In general, we found the expected trends for all six deployments. A pH sensor malfunction on the BFS1 made this performance indicator unusable for stations BPA, BPC, and SLB. No silica data was available for station BPB. However, all available indicators at these stations were consistent with proper chamber performance.

Table 5-5. Summary of performance indicators for the flux study.

<b>Parameter expected</b>	<b>Oxygen Flux (-)</b>	<b>Silica Flux (+)</b>	<b>pH Trend (-)</b>	<b>Mn Flux (+)</b>	<b>Accept</b>
<b>BPA</b>	-	n/a**	n/a*	+	y
<b>BPB</b>	-	n/a**	-	+	y
<b>BPC</b>	-	+	n/a*	+	y
<b>SLA</b>	-	+	-	+	y
<b>SLB</b>	-	+	n/a*	+	y
<b>SLC</b>	-	+	-	+	y

\*pH sensor malfunctioned

\*\*silica not analyzed at this station

Oxygen variations in the chambers were monitored to assure maintenance of ambient oxygen levels, proper chamber seal, and to evaluate sediment oxygen uptake. The oxygen is maintained within a “window” of the ambient level measured at the time of deployment. Figure 5-30 below shows a typical time trend for oxygen in the controlled chamber. The oxygen level is allowed to drop until it reaches the lower window level, and then the diffusion system is pressurized and the oxygen level rises until the upper window level is reached. The system is then vented, and this process repeats as needed during the deployment. Oxygen levels were effectively maintained during all deployments with the exception of P04-3bio and P17-1bio, where the deployment design called for allowing anoxic conditions to develop. Oxygen uptake rates are quantified

from the initial ~2 h of data during the first oxygen cycle descent. These rates are summarized in Table 5-6.

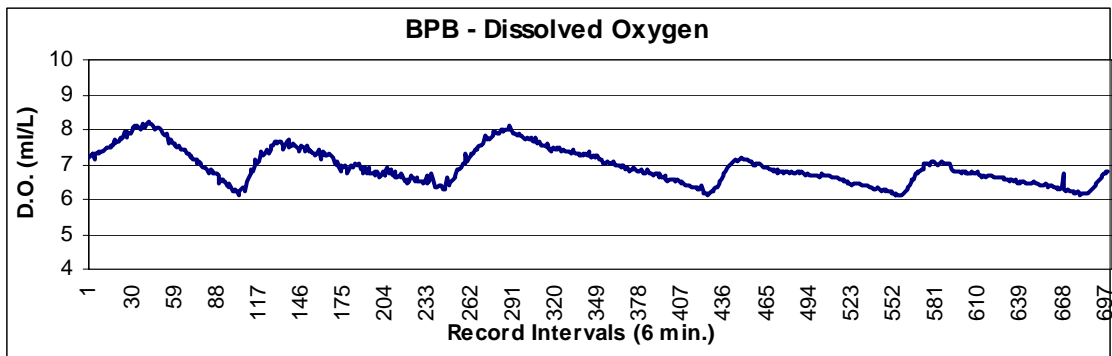


Figure 5-30. Time-course variation of dissolved oxygen in the oxygen-controlled deployment at P04-3a. Vertical axis is dissolved oxygen concentration, and horizontal axis is sample record at 6 min intervals.

At two stations (BPA and SLB), the oxygen levels were allowed to drop naturally without an attempt to maintain ambient levels. These deployments were designed to evaluate the response of non redox sensitive constituents to a “bioinhibited” condition. The purpose of these deployments was to determine if diffusive fluxes could be quantified in the absence of significant biological irrigation. Results for BPA are shown in Figure 5-31 below. Although oxygen levels approached zero near the end, anoxic conditions were not produced during any significant portion of the deployment. At SLB, the initial oxygen uptake rate was comparable (see Table 5-6), with the result that oxic conditions persisted throughout the deployment at this station as well. Based on these results, only limited bioinhibition may have occurred near the end of the deployments at BPA and SLB.

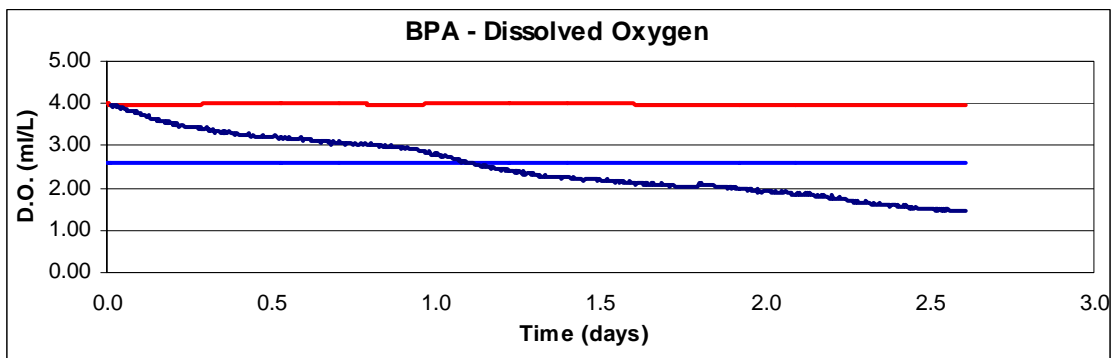


Figure 5-31. Time-course variation of dissolved oxygen in the “bioinhibited” (no oxygen control) deployment at BPA. Vertical axis is dissolved oxygen concentration, and horizontal axis is sample record at 6 min intervals.

In the properly sealed BFSD 2 chamber, the pH will generally show a decreasing trend as the breakdown of organic matter at the sediment water interface drives CO<sub>2</sub> into the

chamber water. This decreasing trend was observed during all BFSD2 deployments, a typical result given in Figure 5-32 below. For the BFSD1, the pH sensor malfunctioned, and the data was not usable.

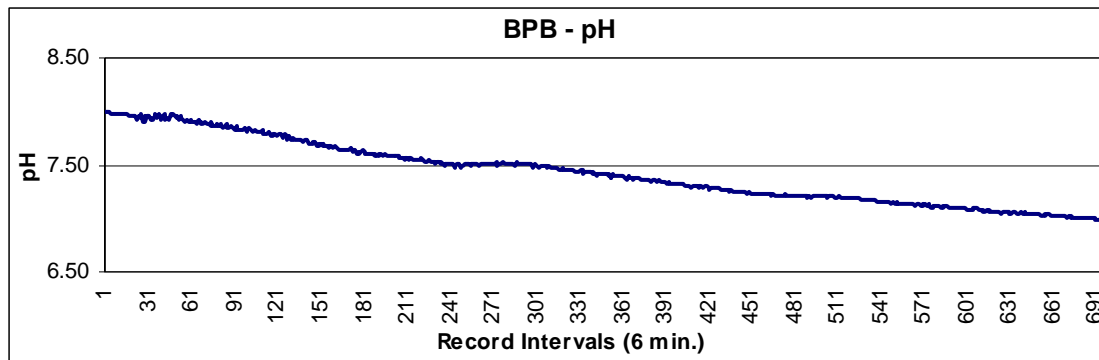


Figure 5-32. Time-course variation in pH the deployment at P04-3bio. Vertical axis is pH concentration, and horizontal axis is sample record at 6 min intervals.

Table 5-6. Oxygen and silica flux rates at the six flux study stations. Oxygen fluxes are in ml/m<sup>2</sup>/d, and silica fluxes are in μm/m<sup>2</sup>/d.

	<b>BPA</b>	<b>BPB</b>	<b>BPC</b>	<b>SLA</b>	<b>SLB</b>	<b>SLC</b>
<b>Oxygen (O<sub>2</sub>)</b>	-450	-1457	-425	-992	-504	-433
<b>Silica (SiO<sub>2</sub>)</b>	n/a	n/a	108	268	149	171

### Metal Fluxes

Results for individual metal fluxes at the six stations in Pearl Harbor are shown in Table 5-7 - Table 5-12 and Figure 5-33 - Figure 5-40. Flux rates are shown for eight metals including As, Cu, Cd, Pb, Ni, Mn, Ag, and Zn. Flux rates were calculated based on the time series concentrations of samples collected from the BFSDs at the four sites. The flux rates were corrected for chamber dilution that occurs during the sampling process. Flux rates were then calculated from the linear regression of concentration versus time. In each case, the fluxes (regression slopes) were statistically compared to the blank chamber flux (the flux with no sediment present) using the Student's t-test. Results for each of these metal are summarized below. Fluxes for the other metals that were measured including Al, Ch, Fe, Hg, Se, and Sn have not been quantified because they are not generally viewed to be COCs at the site, and there is currently no chamber blank to use as a basis for comparison. Overall summaries for metal fluxes are shown in Table 5-13 - Table 5-14 and Figure 5-41.



## Arsenic

Arsenic fluxes were positive at five of the six stations, the exception being SLB. Arsenic flux rates ranged from a low of  $-34 \mu\text{g}/\text{m}^2/\text{day}$  (SLB) to a high of  $80 \mu\text{g}/\text{m}^2/\text{day}$  (SLA). All fluxes were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Arsenic concentrations in the flux chambers at the six stations are shown in Figure 5-33. The mean flux from the three deployments at BP was  $33 \pm 14 \mu\text{g}/\text{m}^2/\text{day}$  ( $\pm$  one standard deviation). The mean flux from the three deployments at SL was  $21 \pm 57 \mu\text{g}/\text{m}^2/\text{day}$ . Thus the results for the two sites were quite comparable, though the variability at SL was somewhat higher.

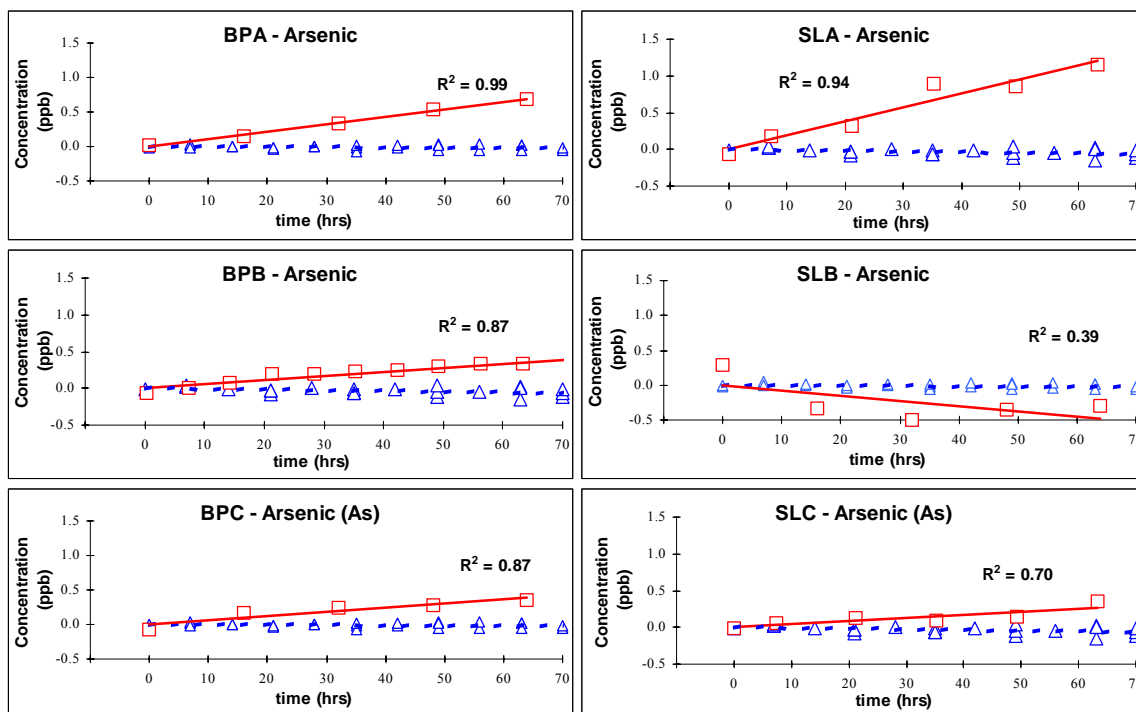


Figure 5-33. Time-series plots for Arsenic in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Copper

Copper fluxes were positive at five of the six stations, with a negative flux only at BPB. Copper flux rates ranged from a low of  $-71 \mu\text{g}/\text{m}^2/\text{day}$  (BPB) to a high of  $140 \mu\text{g}/\text{m}^2/\text{day}$  (BPC). All fluxes were distinguishable from blanks at  $p < 0.20$  with the exception of SLA and SLC. Time-series plots for Copper concentrations in the flux chambers at the six stations are shown in Figure 5-34. The mean flux from the three deployments at BP was  $26 \pm 107 \mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $20 \pm 22 \mu\text{g}/\text{m}^2/\text{day}$ . Thus the overall results for the two sites were quite comparable, though the variability at BP was somewhat higher.

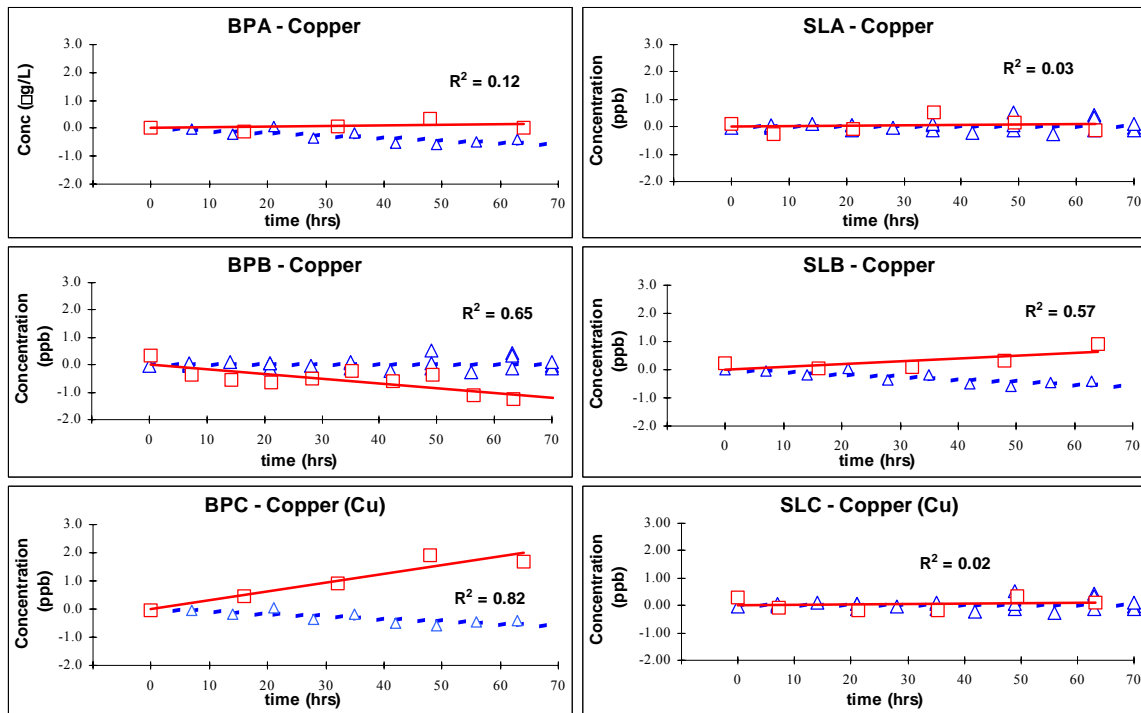


Figure 5-34. Time-series plots for Copper in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Cadmium

Cadmium fluxes were positive at five of the six stations, with a negative flux only at BPA. Cadmium flux rates ranged from a low of  $-1.7 \mu\text{g}/\text{m}^2/\text{day}$  (BPA) to a high of  $5.7 \mu\text{g}/\text{m}^2/\text{day}$  (SLC). All fluxes were distinguishable from blanks at  $p < 0.20$  with the exception of BPA and BPC. Time-series plots for Cadmium concentrations in the flux chambers at the six stations are shown in Figure 5-35. The mean flux from the three deployments at BP was  $0.0 \pm 1.5 \mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $3.5 \pm 1.9 \mu\text{g}/\text{m}^2/\text{day}$ . Thus the SL site generally had stronger and more consistent fluxes of Cadmium compared to the BP site.

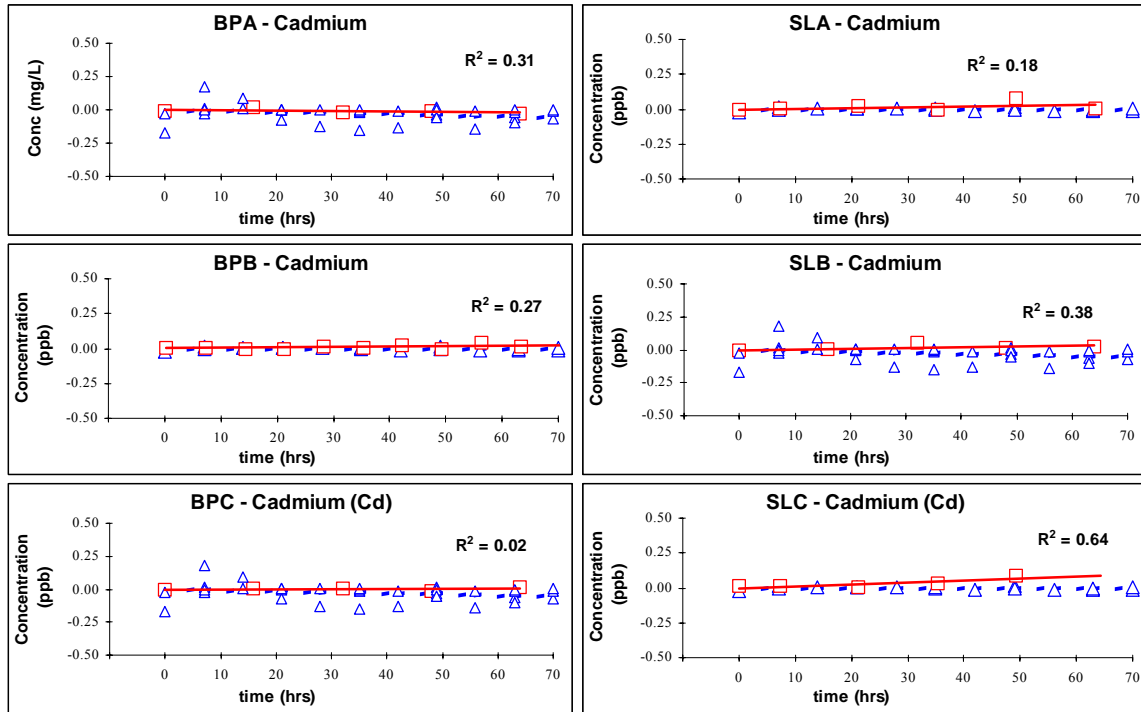


Figure 5-35. Time-series plots for Cadmium in the BFS chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Lead

Lead fluxes were positive at five of the six stations, with a negative flux only at both SLA. Lead flux rates ranged from a low of  $-11 \mu\text{g}/\text{m}^2/\text{day}$  (SLA) to a high of  $42 \mu\text{g}/\text{m}^2/\text{day}$  (BPC). All fluxes were distinguishable from blanks at  $p < 0.20$  with the exception of SLB. Time-series plots for Lead concentrations in the flux chambers at the six stations are shown in Figure 5-36. The mean flux from the three deployments at BP was  $32 \pm 13 \mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $3 \pm 12 \mu\text{g}/\text{m}^2/\text{day}$ . Thus the pattern for Lead was different than for Cadmium with a higher mean flux BP compared to SL.

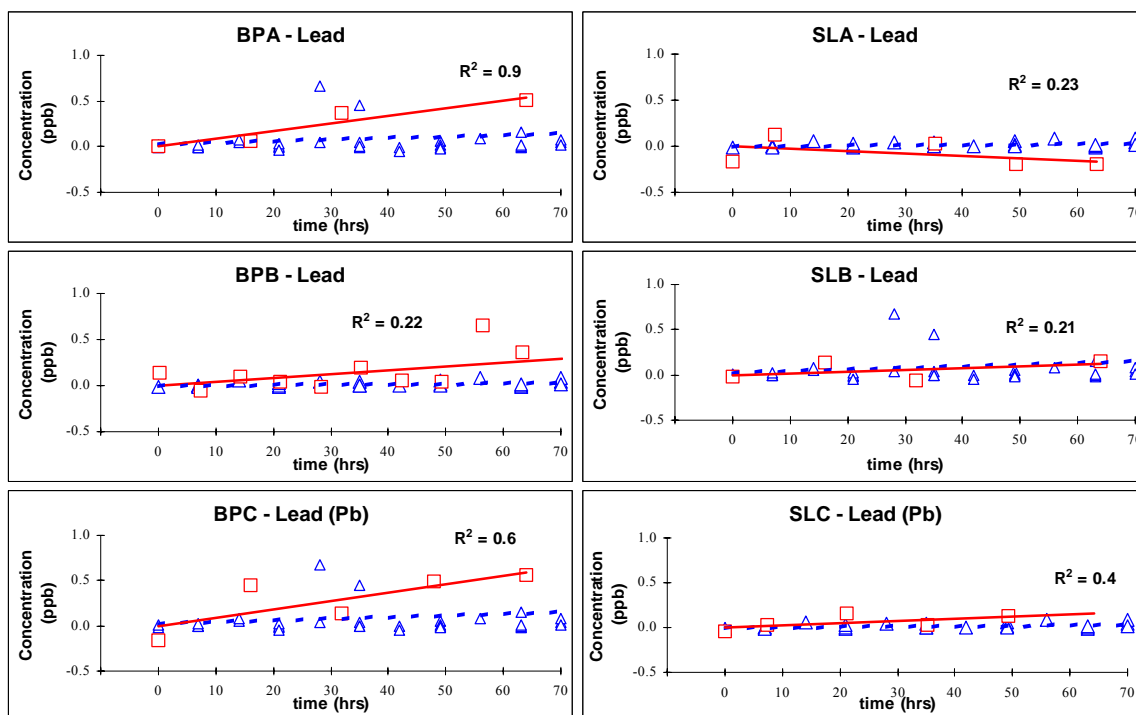


Figure 5-36. Time-series plots for Lead in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Nickel

Nickel fluxes were positive at all six stations. Nickel flux rates ranged from a low of 4  $\mu\text{g}/\text{m}^2/\text{day}$  (BPA) to a high of 123  $\mu\text{g}/\text{m}^2/\text{day}$  (SLA). All fluxes were distinguishable from blanks at  $p < 0.20$  with the exception of BPA and BPC. Time-series plots for Nickel concentrations in the flux chambers at the six stations are shown in Figure 5-37. The mean flux from the three deployments at BP was  $25 \pm 30$   $\mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $97 \pm 44$   $\mu\text{g}/\text{m}^2/\text{day}$ . Thus the pattern for Nickel was similar to that of Cadmium with a higher mean flux at SL compared to BP.

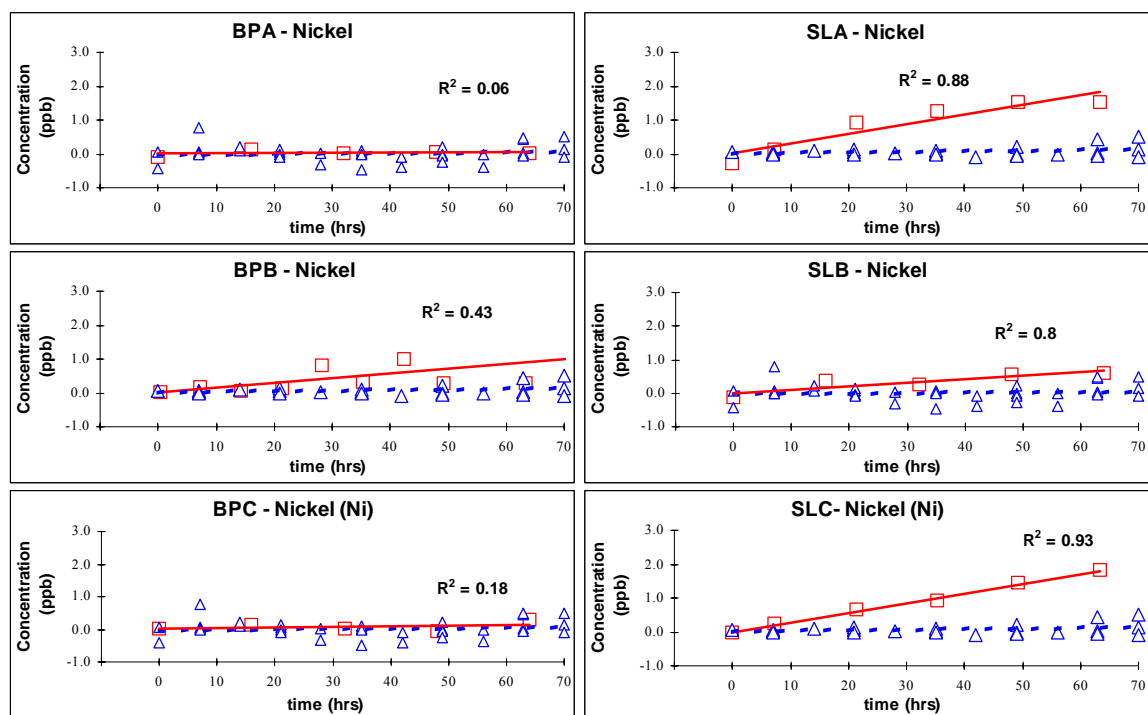


Figure 5-37. Time-series plots for Nickel in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Manganese

Manganese fluxes were positive at all stations. Manganese flux rates ranged from a low of  $238 \mu\text{g}/\text{m}^2/\text{day}$  (BPC) to a high of  $2172 \mu\text{g}/\text{m}^2/\text{day}$  (SLB). Fluxes at all stations were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Manganese concentrations in the flux chambers at the six stations are shown in Figure 5-38. The mean flux from the three deployments at BP was  $2116 \pm 3090 \mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $1245 \pm 803 \mu\text{g}/\text{m}^2/\text{day}$ . In general, the Manganese flux at both sites was similar, however the mean and variability of was skewed high at BP due to the exceptionally high flux at BPA.

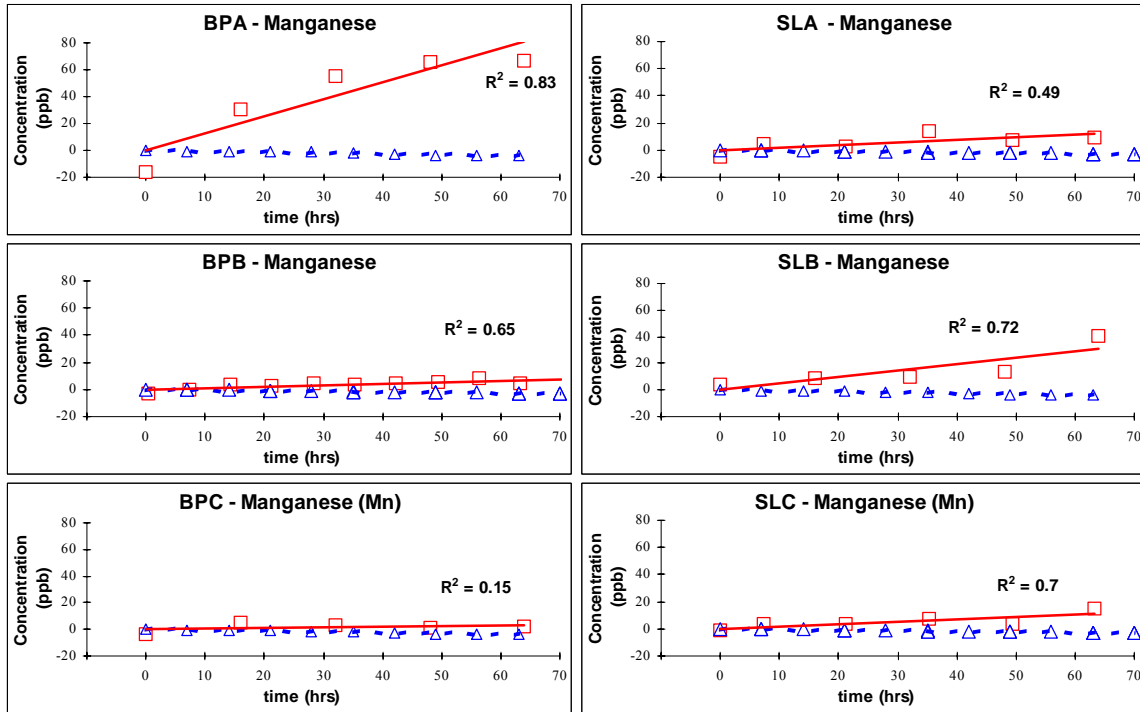


Figure 5-38. Time-series plots for Manganese in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Silver

Silver fluxes were positive at two stations, negative at one stations, and below detection at three stations. Silver flux rates ranged from a low of  $-1.3 \mu\text{g}/\text{m}^2/\text{day}$  (SLB) to a high of  $2.8 \mu\text{g}/\text{m}^2/\text{day}$  (BPA). Fluxes at BPA, BPC and SLB were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Silver concentrations in the flux chambers at the six stations are shown in Figure 5-39. The mean flux from the three deployments at P04 was  $2.3 \pm 0.6 \mu\text{g}/\text{m}^2/\text{day}$ . The mean flux at SL was  $-1.3 \mu\text{g}/\text{m}^2/\text{day}$ , but was based on only the result at SLB. Thus the pattern for Silver was similar to that of Lead with a higher mean flux BP compared to SL.

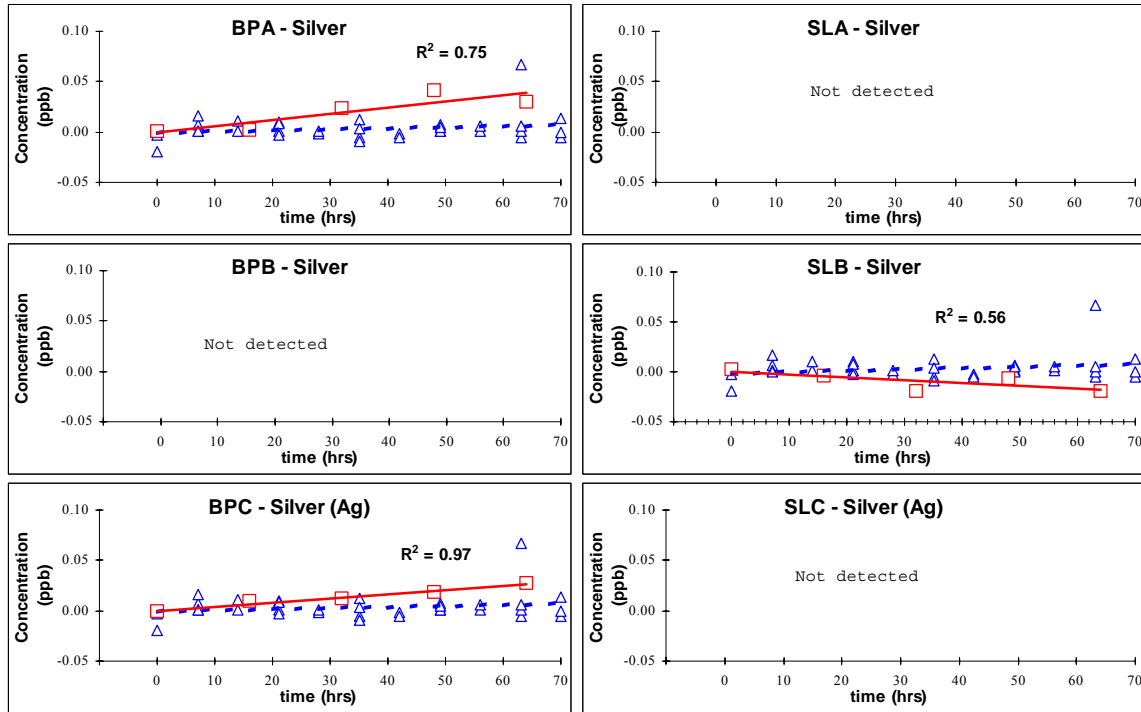


Figure 5-39. Time-series plots for Silver in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Zinc

Zinc fluxes were positive at all six stations. Zinc flux rates ranged from a low of 179  $\mu\text{g}/\text{m}^2/\text{day}$  (SLA) to a high of 499  $\mu\text{g}/\text{m}^2/\text{day}$  (SLC). All fluxes were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Zinc concentrations in the flux chambers at the six stations are shown in Figure 5-40. The mean flux from the three deployments at BP was  $298 \pm 99$   $\mu\text{g}/\text{m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $356 \pm 163$   $\mu\text{g}/\text{m}^2/\text{day}$ . Thus the Zinc fluxes at the two sites were comparable, though the variability at SL was somewhat higher than at BP.

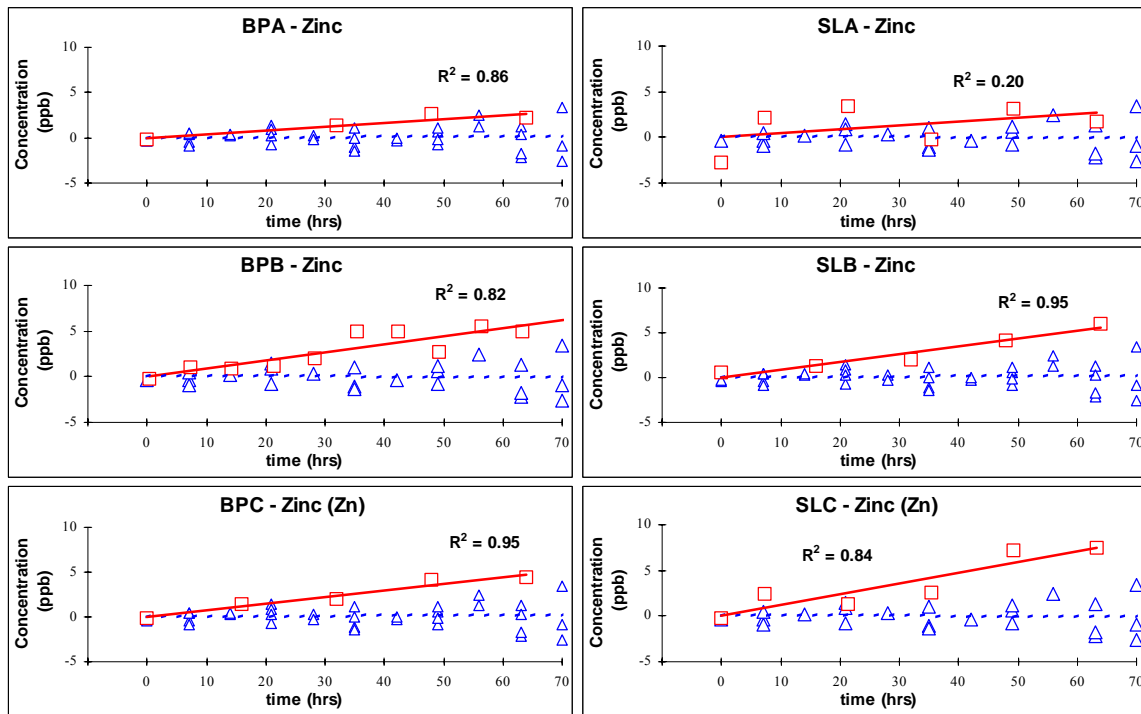


Figure 5-40. Time-series plots for Zinc in the BFSD chambers. Red squares indicate concentrations for station samples, and blue triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.



Table 5-7. BFSD results from site BPA. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison. Secondary flux rates for Mn and Si are based on the initial three samples.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux ( $\mu\text{g}/\text{m}^2/\text{day}$ )	
	( $\mu\text{g}/\text{m}^2/\text{day}$ )*	( $\mu\text{g}/\text{m}^2/\text{day}$ )	(%)	Average	+/- 95% C.L.
Arsenic (As)	48.4	6.1	100%	-1.4	1.7
Copper (Cu)	9.9	49.0	99.1%	-52	16
Cadmium (Cd)	-1.7	4.6	38.0%	-4.8	3.0
Lead (Pb)	38	37	88.3%	15	11
Nickel (Ni)	3.9	27.7	8.0%	3.1	13
Manganese (Mn)	5683	4694	100.0%	-382	38
Silver (Ag)	2.8	2.9	99.8%	0.6	0.5
Zinc (Zn)	186	230	99.5%	7.6	47

Table 5-8. BFSD results from site BPB. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux ( $\mu\text{g}/\text{m}^2/\text{day}$ )	
	( $\mu\text{g}/\text{m}^2/\text{day}$ )*	( $\mu\text{g}/\text{m}^2/\text{day}$ )	(%)	Average	+/- 95% C.L.
Arsenic (As)	23	6.9	100%	-5.2	2.1
Copper (Cu)	-71	39	100.0%	2.8	8.7
Cadmium (Cd)	1.3	1.6	98.1%	-0.5	0.75
Lead (Pb)	17	25	99.0%	3.2	1.6
Nickel (Ni)	59	56	100.0%	10	7.3
Manganese (Mn)	428	238	100.0%	-265	7.5
Silver (Ag)	ND	N/A	N/A	0.64	0.68
Zinc (Zn)	374	134	100.0%	-3.4	65

Table 5-9. BFSD results from site BPC. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison. Secondary flux rates for Si are based on the initial three samples.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux ( $\mu\text{g}/\text{m}^2/\text{day}$ )	
	( $\mu\text{g}/\text{m}^2/\text{day}$ )*	( $\mu\text{g}/\text{m}^2/\text{day}$ )	(%)	Average	+/- 95% C.L.
Arsenic (As)	27	19	100%	-1.4	1.7
Copper (Cu)	140	88	100.0%	-52	16
Cadmium (Cd)	0.26	3.5	68.6%	-4.8	3.0
Lead (Pb)	42	62	95.3%	15	11
Nickel (Ni)	11	42	38.8%	3.1	13
Manganese (Mn)	237	1025	98.0%	-382	38
Silver (Ag)	1.9	0.56	96.2%	0.56	0.55
Zinc (Zn)	332	141	100.0%	7.6	47

Table 5-10. BFSD results from site SLA. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux ( $\mu\text{g}/\text{m}^2/\text{day}$ )	
	( $\mu\text{g}/\text{m}^2/\text{day}$ )*	( $\mu\text{g}/\text{m}^2/\text{day}$ )	(%)	Average	+/- 95% C.L.
Arsenic (As)	80	29	100%	-5.2	2.1
Copper (Cu)	8.3	66	41.1%	2.8	8.7
Cadmium (Cd)	2.3	7.0	95.7%	-0.52	0.75
Lead (Pb)	-11	38	99.8%	3.2	1.6
Nickel (Ni)	123	63	100.0%	10	7.3
Manganese (Mn)	798	1121	100.0%	-265	7.5
Silver (Ag)	ND	N/A	N/A	0.64	0.68
Zinc (Zn)	179	500	95.0%	-3.4	65

Table 5-11. BFSD results from site SLB. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison. Secondary flux rates for As, Mn and Si are based on the initial three samples.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux (mg/m <sup>2</sup> /day)	
	(mg/m <sup>2</sup> /day)*	(mg/m <sup>2</sup> /day)	(%)	Average	+/- 95% C.L.
Arsenic (As)	-34	78	100%	-1.4	1.7
Copper (Cu)	46	73	99.9%	-52	16
Cadmium (Cd)	2.5	6.0	88.6%	-4.8	3.0
Lead (Pb)	8.6	51	13.5%	15	11
Nickel (Ni)	46	42	99.0%	3.1	13
Manganese (Mn)	2171	2470	100.0%	-382	38
Silver (Ag)	-1.3	2.1	98.2%	0.56	0.55
Zinc (Zn)	389	170	100.0%	7.6	47

Table 5-12. BFSD results from site SLC. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate. Results from the blank study are shown for comparison.

Metal	Flux	+/- 95% C.L.	Flux rate Confidence	Triplicate Blank Flux (µg/m <sup>2</sup> /day)	
	(µg/m <sup>2</sup> /day)*	(µg/m <sup>2</sup> /day)	(%)	Average	+/- 95% C.L.
Arsenic (As)	18	14	100%	-5.2	2.1
Copper (Cu)	6.2	55	29.8%	2.8	8.7
Cadmium (Cd)	5.7	7.8	100.0%	-0.52	0.75
Lead (Pb)	11	25	99.3%	3.2	1.6
Nickel (Ni)	121	13	100.0%	10	7.3
Manganese (Mn)	766	813	100.0%	-265	7.5
Silver (Ag)	ND	N/A	N/A	0.64	0.68
Zinc (Zn)	499	306	100.0%	-3.4	65

Table 5-13. Summary of BFSD results for metals from site BP. Shaded cells indicate flux rates that were statistically distinguishable from blanks at  $p < 0.20$ .

	<b>BPA</b>	<b>BPB</b>	<b>BPC</b>	<b>Min</b>	<b>Max</b>	<b>Mean</b>	<b>Std</b>
<b>Arsenic (As)</b>	48	23	27	23	48	33	14
<b>Copper (Cu)</b>	10	-71	140	-71	140	26	107
<b>Nickel (Ni)</b>	4	59	11	4	59	25	30
<b>Cadmium (Cd)</b>	-1.7	1.3	0.3	-1.7	1.3	0.0	1.5
<b>Lead (Pb)</b>	38	17	42	17	42	32	13
<b>Silver (Ag)</b>	2.8	ND	1.9	1.9	2.8	2.3	0.6
<b>Manganese (Mn)</b>	5683	428	238	238	5683	2116	3090
<b>Zinc (Zn)</b>	186	374	332	186	374	298	99

Table 5-14. Summary of BFSD results for metals from site SL. Shaded cells indicate flux rates that were statistically distinguishable from blanks at  $p < 0.20$ .

	<b>SLA</b>	<b>SLB</b>	<b>SLC</b>	<b>Min</b>	<b>Max</b>	<b>Mean</b>	<b>Std</b>
<b>Arsenic (As)</b>	80	-34	18	-34	80	21	57
<b>Copper (Cu)</b>	8	46	6	6	46	20	22
<b>Nickel (Ni)</b>	123	47	121	47	123	97	44
<b>Cadmium (Cd)</b>	2.3	2.5	5.7	2.3	5.7	3.5	1.9
<b>Lead (Pb)</b>	-11	9	11	-11	11	3	12
<b>Silver (Ag)</b>	ND	-1.3	ND	-1.3	-1.3	-1.3	NA
<b>Manganese (Mn)</b>	798	2172	766	766	2172	1245	803
<b>Zinc (Zn)</b>	179	389	499	179	499	356	163

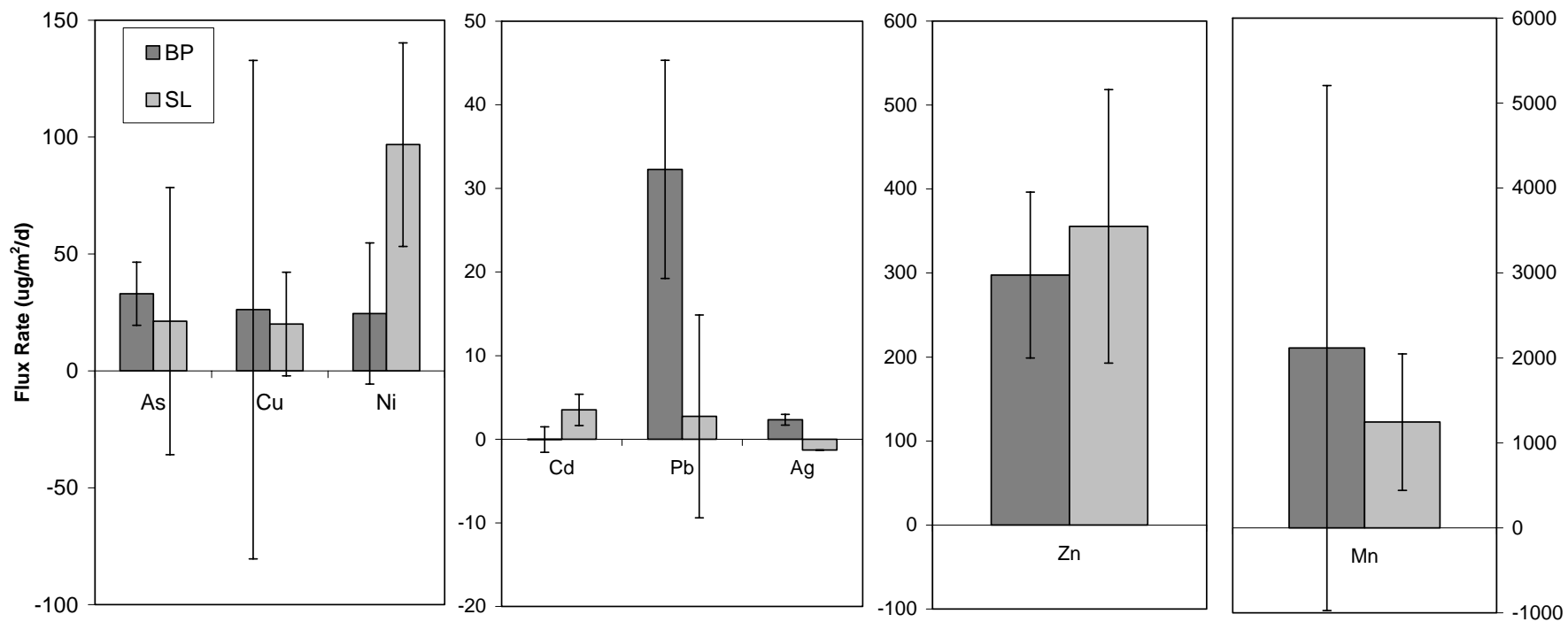


Figure 5-41. Summary plot for mean flux rates of metals at BP and SL. Note variation in vertical scale for different groups of metals. Error bars are standard deviations based on the variability of the three deployments within each area.

**PAH Fluxes**

Results for PAH fluxes at the five stations in Pearl Harbor are shown in Table 5-15 - Table 5-20. Flux rates are shown for eight PAHs including Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, and Pyrene. Flux rates were calculated based on the time series concentrations of samples collected from the BFSDs at the six sites. The flux rates were corrected for chamber dilution that occurs during the sampling process. In addition, flux rates for Naphthalene, Fluoranthene, and Pyrene were corrected for blank flux rates. Flux rates were then calculated from the linear regression of concentration versus time. In each case, the fluxes (regression slopes) were statistically compared to the blank chamber flux (the flux with no sediment present) using the Student's t-test. Results for each of these PAHs are summarized below. Fluxes for the other PAHs that were measured have not been quantified because either the concentrations were below detection, they are not generally viewed to be COCs at the site, and/or there is currently no chamber blank to use as a basis for comparison. At station BPA, the high number of non-detects made quantification of PAH fluxes impractical. Overall summaries for metal fluxes are shown in Table 5-21 - Table 5-22 and Figure 5-50.

## Naphthalene

Naphthalene fluxes were positive at three stations, negative at two stations, and not detected at one station. Naphthalene flux rates ranged from a low of  $-564 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $711 \text{ ng/m}^2/\text{day}$  (BPB). Note that the fluxes for Naphthalene were corrected for a negative blank flux by subtracting the blank regression from the station regression. Only the flux at BPB was distinguishable from blank at  $p < 0.20$ . Time-series plots for Naphthalene concentrations in the flux chambers at the six stations are shown in Figure 5-42. The mean flux from the three deployments at BP was  $247 \pm 657 \text{ ng/m}^2/\text{day}$  ( $\pm$  one standard deviation). The mean flux from the three deployments at SL was  $-178 \pm 334 \text{ ng/m}^2/\text{day}$ . Thus the mean flux for BP was higher than that for SL, although both sites had fairly high variability.

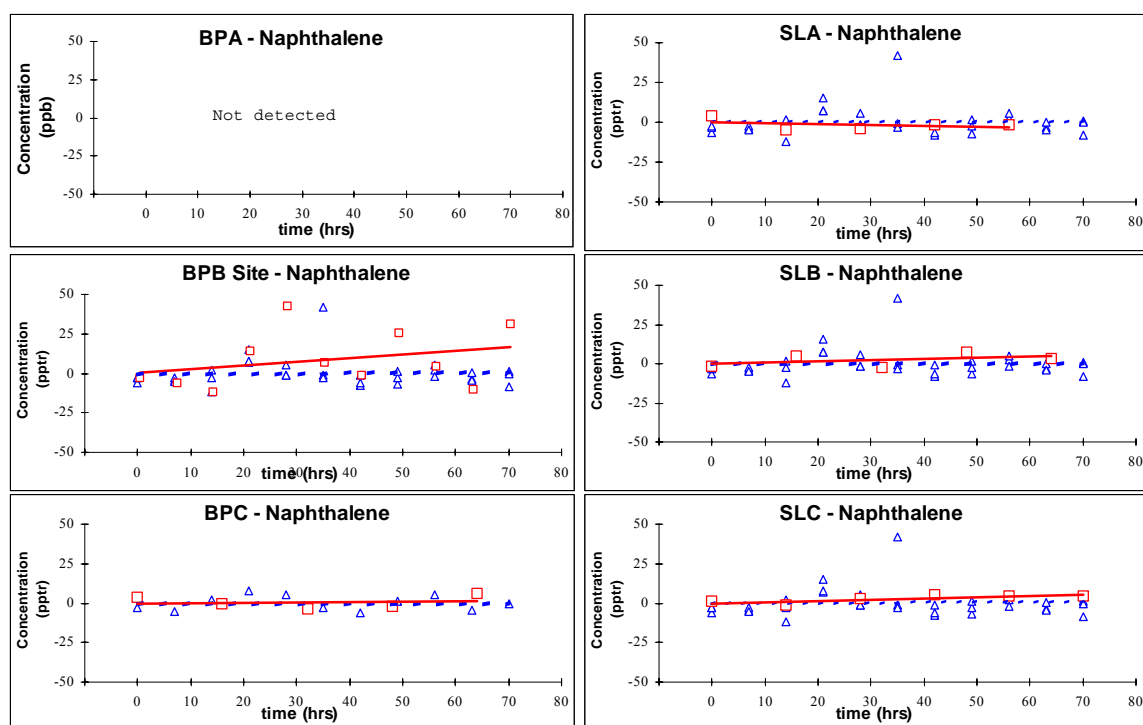


Figure 5-42. Time-series plots for Naphthalene in the BFS chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

### Acenaphthylene

Acenaphthylene fluxes were negative at four stations, positive at one stations, and below detection at one station.. Acenaphthylene flux rates ranged from a low of  $-130 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $107 \text{ ng/m}^2/\text{day}$  (BPB). All SL stations were distinguishable from blank at  $p < 0.20$ , but at the BP site, only the flux at BPC was distinguishable from blank. Time-series plots for Acenaphthylene concentrations in the flux chambers at the six stations are shown in Figure 5-43. The mean flux from the three deployments at BP was  $1 \pm 149 \text{ ng/m}^2/\text{day}$  ( $\pm$  one standard deviation). The mean flux from the three deployments at SL was  $-78 \pm 45 \text{ ng/m}^2/\text{day}$ . Thus, the flux at BP appears to be somewhat higher than at P04, however BP also had higher within-site variability.

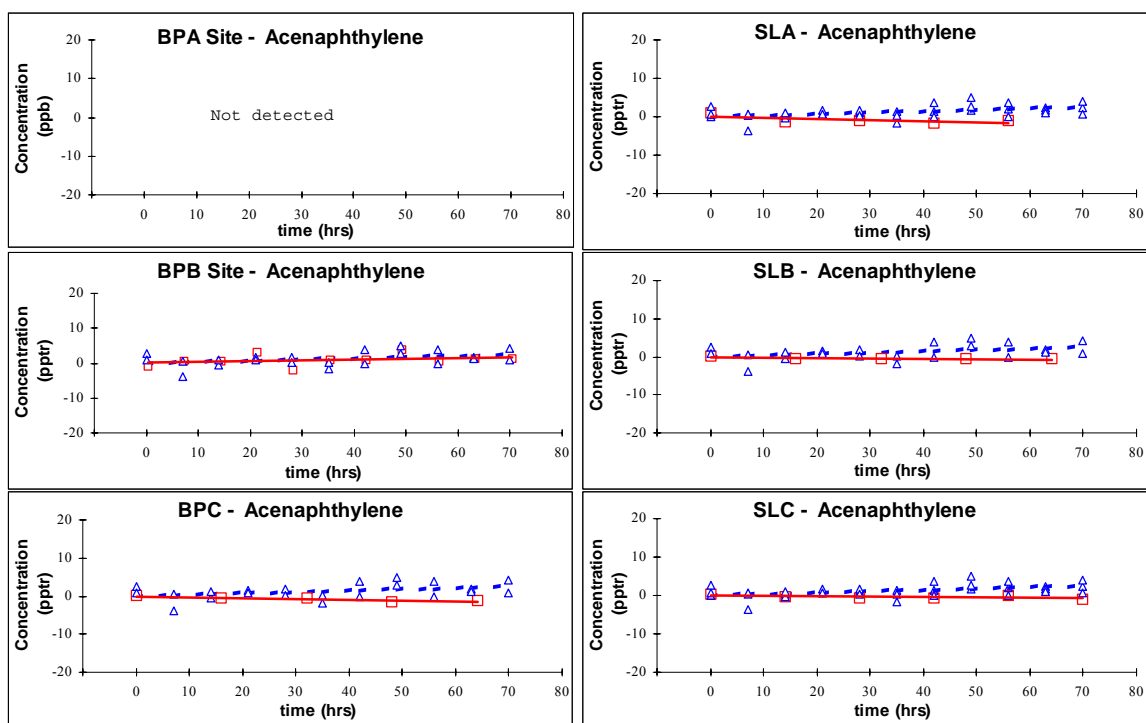


Figure 5-43. Time-series plots for Acenaphthylene in the BFSF chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.



### Acenaphthene

Acenaphthene fluxes were negative at four stations and not detected at two stations. Acenaphthene flux rates ranged from a low of  $-1392 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $-317 \text{ ng/m}^2/\text{day}$  (BPC). Fluxes at all four stations were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Acenaphthene concentrations in the flux chambers at the six stations are shown in Figure 5-44. The mean flux from the three deployments at BP was  $-852 \pm 757 \text{ ng/m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $-1060 \pm 469 \text{ ng/m}^2/\text{day}$ . Thus the pattern for Acenaphthene fairly consistent uptake by the sediments at both BP and SL.

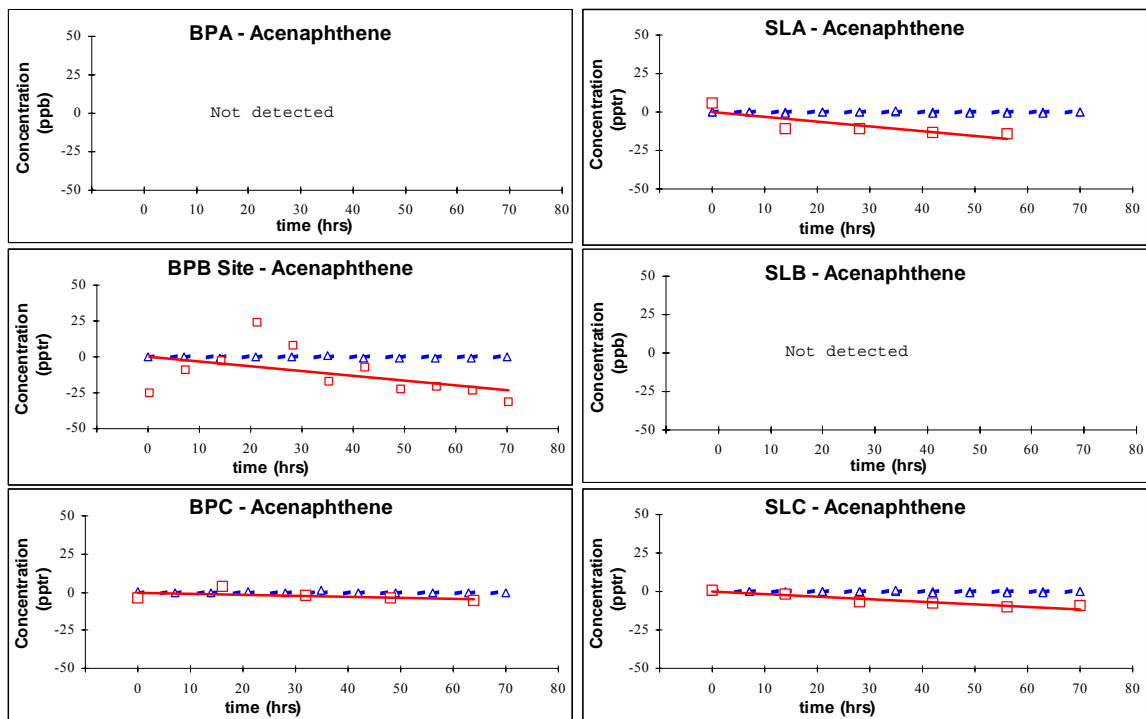


Figure 5-44. Time-series plots for Acenaphthene in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Fluorene

Fluorene fluxes were positive at one stations (BPC), negative at three stations (BPB, SLA, and SLC), and below detection at BPA and SLB. Fluorene flux rates ranged from a low of  $-704 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $271 \text{ ng/m}^2/\text{day}$  (BPC). Fluxes at four stations (BPB, BPC, SLA and SLC) were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Fluorene concentrations in the flux chambers at the six stations are shown in Figure 5-45. The mean flux from the three deployments at BP was  $-44 \pm 445 \text{ ng/m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $-411 \pm 415 \text{ ng/m}^2/\text{day}$ . Thus Fluorene showed both positive and negative fluxes in both areas, with resulting negative mean rates. Within-site variability was somewhat higher at P17.

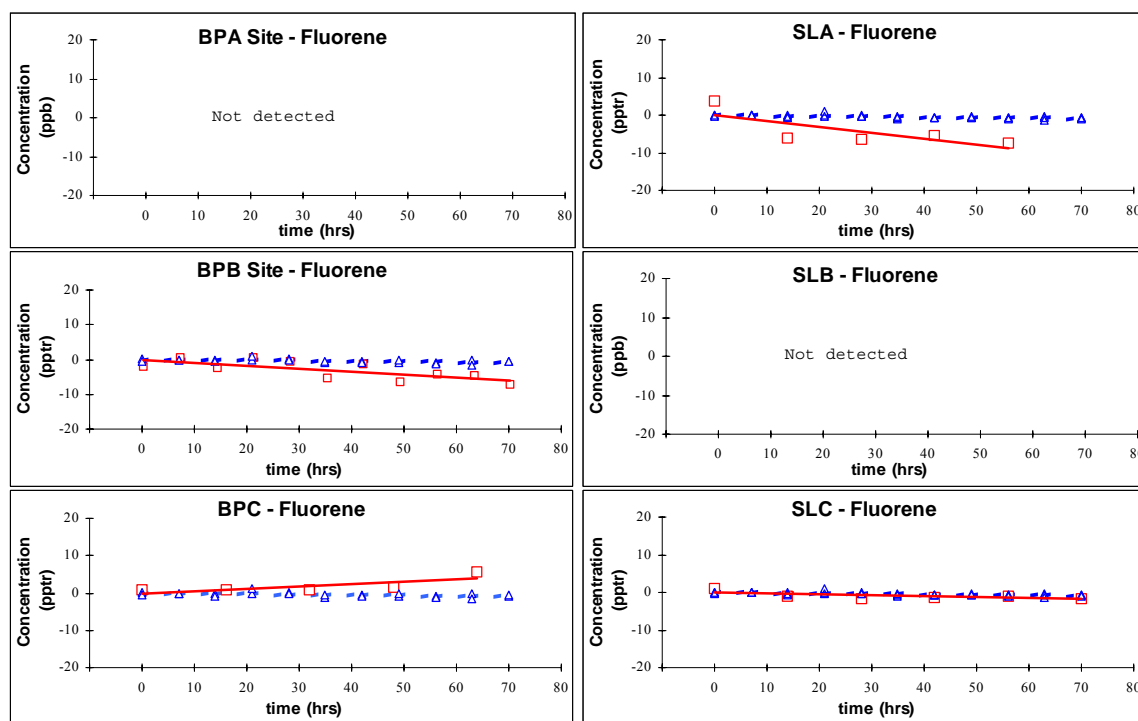


Figure 5-45. Time-series plots for Fluorene in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Phenanthrene

Phenanthrene fluxes were positive at two stations, negative at three stations, and not detected at one station. Phenanthrene flux rates ranged from a low of  $-1040 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $48 \text{ ng/m}^2/\text{day}$  (BPC). Fluxes at all five stations were statistically distinguishable from blanks at  $p < 0.20$ . Time-series plots for Phenanthrene concentrations in the flux chambers at the six stations are shown in Figure 5-46. The mean flux from the two deployments at BP was  $-76 \pm 797 \text{ ng/m}^2/\text{day}$ , while the mean flux from the three deployments at SL was  $-339 \pm 634 \text{ ng/m}^2/\text{day}$ . Thus the pattern for Phenanthrene was fairly similar between the two areas, with the strong negative flux at SLA leading to a negative mean for SL, and the negative flux at BPB leading to a negative mean at BP. Variability at within the two sites was similar.

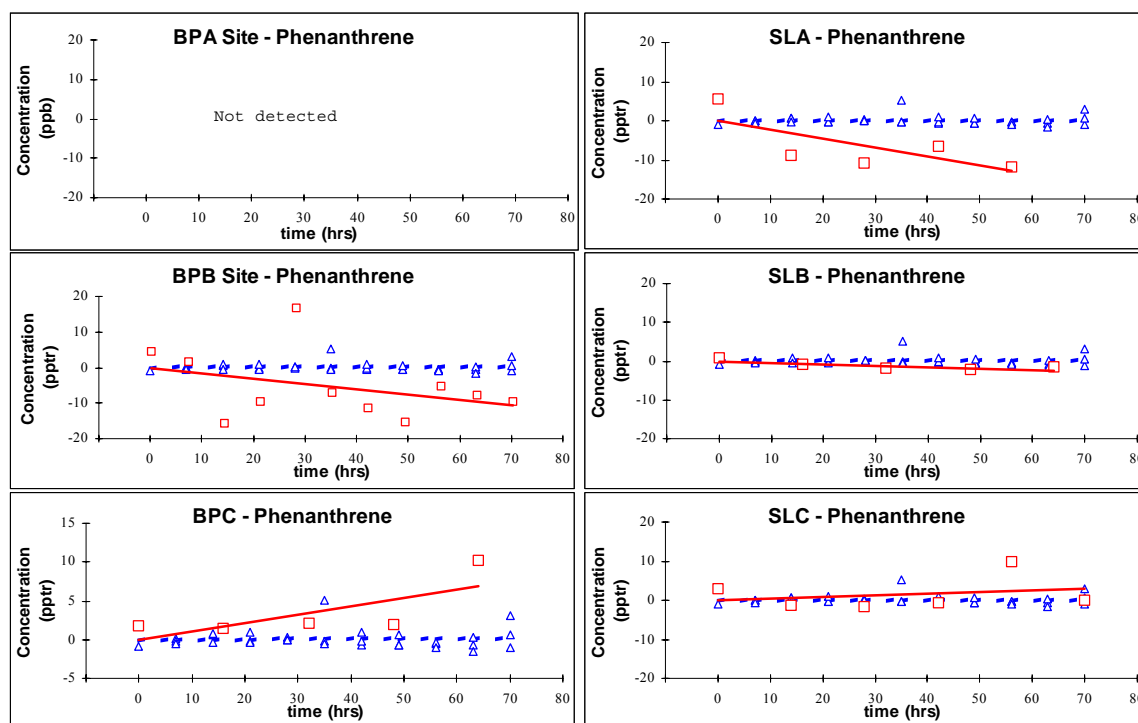


Figure 5-46. Time-series plots for Phenanthrene in the BFSF chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Anthracene

Anthracene fluxes were positive at three stations, negative at two stations, and not detected at one station. Anthracene flux rates ranged from a low of  $-176 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $764 \text{ ng/m}^2/\text{day}$  (BPB). Fluxes at four of the five stations were distinguishable from blanks at  $p < 0.20$ , with the exception being SLB. Time-series plots for Anthracene concentrations in the flux chambers at the six stations are shown in Figure 5-47. The mean flux from the three deployments at BP was  $524 \pm 339 \text{ ng/m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $-39 \pm 140 \text{ ng/m}^2/\text{day}$ . Thus the pattern for Anthracene showed higher fluxes and variability at BP relative to SL.

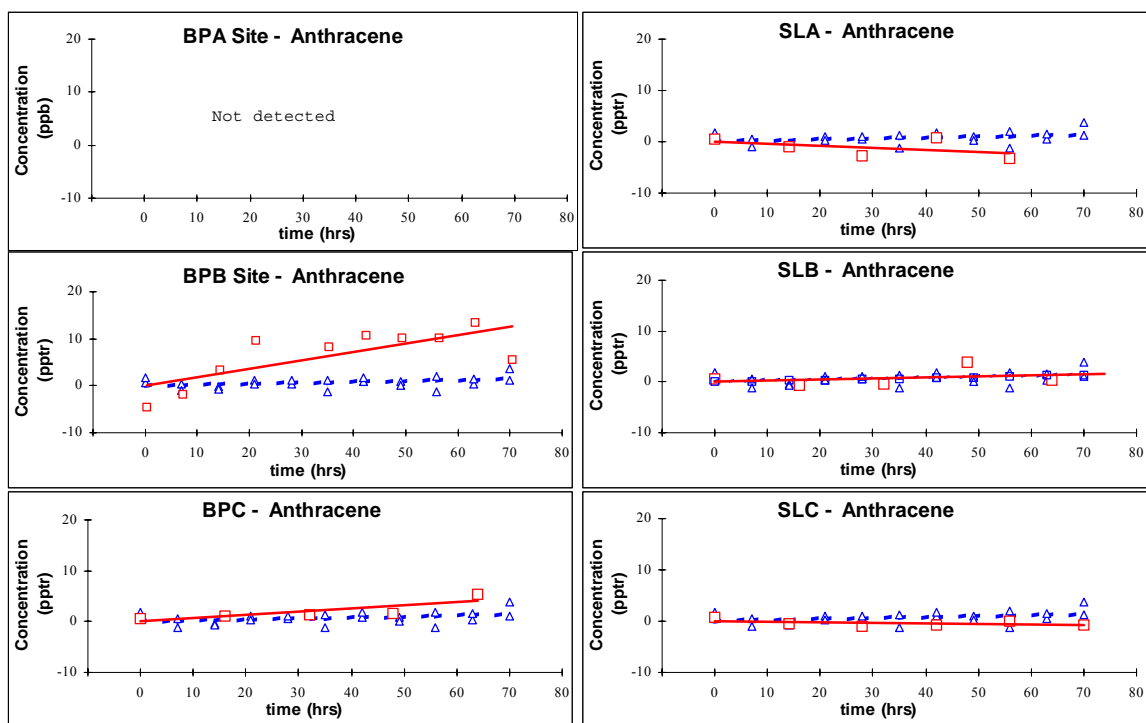


Figure 5-47. Time-series plots for Anthracene in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Fluoranthene

Fluoranthene fluxes were positive at two stations, negative at three stations and not detected at one station. Fluoranthene flux rates ranged from a low of  $-1492 \text{ ng/m}^2/\text{day}$  (SLA) to a high of  $2750 \text{ ng/m}^2/\text{day}$  (BPB). Note that the fluxes for Fluoranthene were corrected for a negative blank flux by subtracting the blank regression from the station regression. Three of five fluxes were distinguishable from blanks at  $p < 0.20$ , exceptions being at SLA and SLB. Time-series plots for Fluoranthene concentrations in the flux chambers at the six stations are shown in Figure 5-48. The mean flux from the three deployments at BP was  $1676 \pm 1518 \text{ ng/m}^2/\text{day}$ . The mean flux from the three deployments at SL was  $-895 \pm 684 \text{ ng/m}^2/\text{day}$ . Thus the results for the two sites indicate higher release of fluoranthene at BP compared to SL.

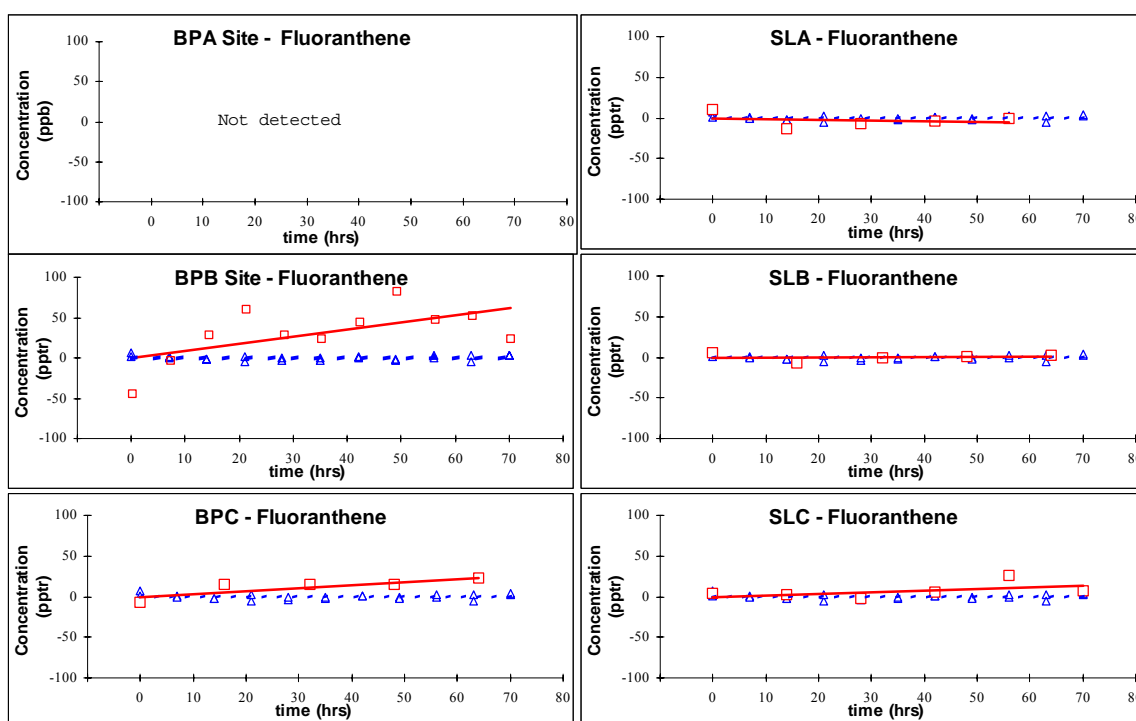


Figure 5-48. Time-series plots for Fluoranthene in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

## Pyrene

Pyrene fluxes were positive at four stations, negative at one station, and not detected at one station. Pyrene flux rates ranged from a low of  $-1020 \text{ ng/m}^2/\text{day}$  (SLB) to a high of  $4666 \text{ ng/m}^2/\text{day}$  (SLC). Note that the fluxes for Pyrene were corrected for a negative blank flux by subtracting the blank regression from the station regression. All fluxes were distinguishable from blanks at  $p < 0.20$ . Time-series plots for Pyrene concentrations in the flux chambers at the six stations are shown in Figure 5-49. The mean flux from the three deployments at BP was  $1919 \pm 386 \text{ ng/m}^2/\text{day}$ . The mean flux from the three deployments at P17 was  $2649 \pm 3183 \text{ ng/m}^2/\text{day}$ . Thus the Pyrene flux and variability at SL was somewhat higher than at BP, although both stations showed consistently positive flux rates.

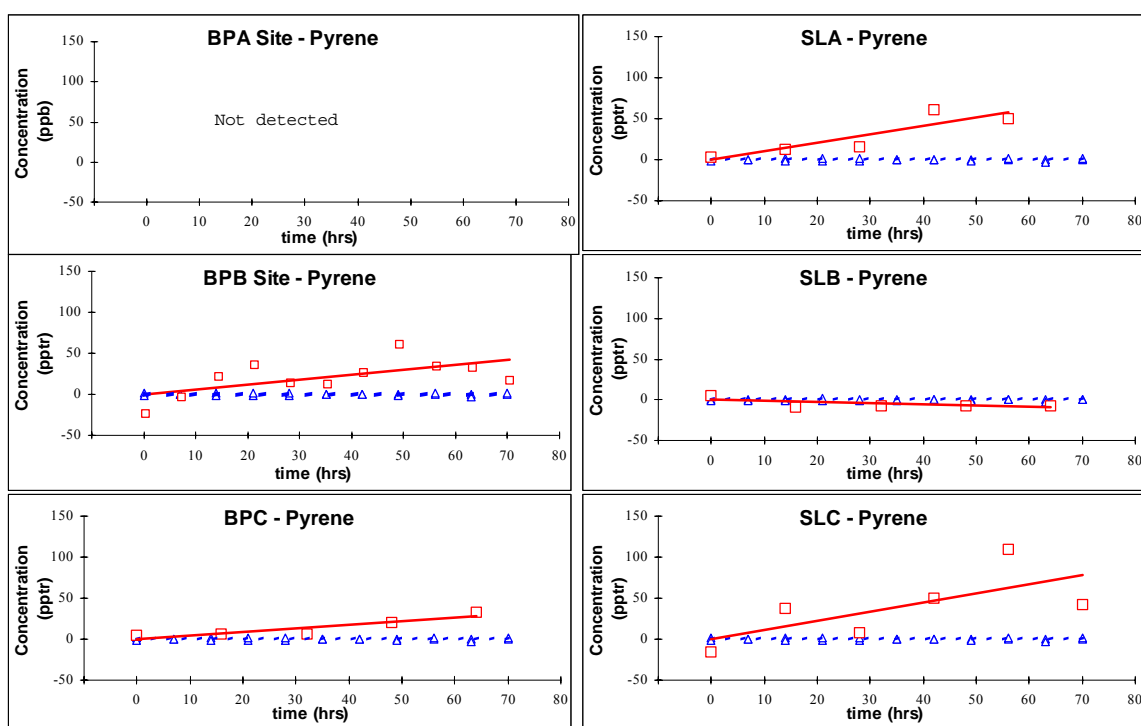


Figure 5-49. Time-series plots for Pyrene in the BFSD chambers. Squares indicate concentrations for station samples, and triangles indicate blank chamber concentrations. Best-fit linear-regression lines are also shown.

Table 5-15. BFSD results from site BPA. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	ND	NA	NA
Acenaphthene	ND	NA	NA
Acenaphthylene	ND	NA	NA
Fluorene	ND	NA	NA
Phenanthrene	ND	NA	NA
Anthracene	ND	NA	NA
Fluoranthene	ND	NA	NA
Pyrene	ND	NA	NA

Table 5-16. BFSD results from site BPB. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	711	2352	93%
Acenaphthene	-1388	1989	91%
Acenaphthylene	107	214	32%
Fluorene	-359	257	100%
Phenanthrene	-640	1228	100%
Anthracene	764	546	100%
Fluoranthene	2750	3651	100%
Pyrene	2192	2392	100%

Table 5-17. BFSD results from site BPC. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	-218	1336	15%
Acenaphthene	-317	1061	89%
Acenaphthylene	-104	80	96%
Fluorene	271	430	100%
Phenanthrene	488	836	100%
Anthracene	284	375	98%
Fluoranthene	603	2137	100%
Pyrene	1645	1653	100%

Table 5-18. BFSD results from site SLA. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	-564	1228	29%
Acenaphthene	-1392	1812	100%
Acenaphthylene	-130	298	96%
Fluorene	-704	1152	100%
Phenanthrene	-1040	1809	100%
Anthracene	-176	598	99%
Fluoranthene	-1492	3190	78%
Pyrene	4302	4463	100%



Table 5-19. BFSD results from site SLB. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	4	1236	43%
Acenaphthene	ND	NA	NA
Acenaphthylene	-55	80	90%
Fluorene	ND	NA	NA
Phenanthrene	-167	231	97%
Anthracene	104	559	15%
Fluoranthene	-1045	1503	5%
Pyrene	-1020	1531	100%

Table 5-20. BFSD results from site SLC. Numbers in the Flux Rate Confidence column indicate the statistical confidence that the measured flux rate is different than the blank flux rate.

PAH	Flux	+/- 95% C.L.	Flux Rate Confidence
	(ng/m <sup>2</sup> /day)*	(ng/m <sup>2</sup> /day)	(%)
Naphthalene	26	406	51%
Acenaphthene	-729	366	100%
Acenaphthylene	-48	73	93%
Fluorene	-118	174	91%
Phenanthrene	192	998	89%
Anthracene	-46	135	95%
Fluoranthene	-149	1991	99%
Pyrene	4666	7373	100%

Table 5-21. Summary of BFSD results for PAHs from site BP. Shaded cells indicate flux rates that were statistically distinguishable from blanks at  $p < 0.20$ .

	<b>BPA</b>	<b>BPB</b>	<b>BPC</b>	<b>Min</b>	<b>Max</b>	<b>Mean</b>	<b>Std</b>
<b>Naphthalene</b>	ND	711	-218	-218	711	247	657
<b>Acenaphthene</b>	ND	-1388	-317	-1388	-317	-852	757
<b>Acenaphthylene</b>	ND	107	-104	-104	107	1	149
<b>Fluorene</b>	ND	-359	271	-359	271	-44	445
<b>Phenanthrene</b>	ND	-640	488	-640	488	-76	797
<b>Anthracene</b>	ND	764	284	284	764	524	339
<b>Fluoranthene</b>	ND	2750	603	603	2750	1676	1518
<b>Pyrene</b>	ND	2192	1645	1645	2192	1919	386

Table 5-22. Summary of BFSD results for PAHs from site SL. Shaded cells indicate flux rates that were statistically distinguishable from blanks at  $p < 0.20$ .

	<b>SLA</b>	<b>SLB</b>	<b>SLC</b>	<b>Min</b>	<b>Max</b>	<b>Mean</b>	<b>Std</b>
<b>Naphthalene</b>	-564	4	26	-564	26	-178	334
<b>Acenaphthene</b>	-1392	ND	-729	-1392	-729	-1060	469
<b>Acenaphthylene</b>	-130	-55	-48	-130	-48	-78	45
<b>Fluorene</b>	-704	ND	-118	-704	-118	-411	415
<b>Phenanthrene</b>	-1040	-167	192	-1040	192	-339	634
<b>Anthracene</b>	-176	104	-46	-176	104	-39	140
<b>Fluoranthene</b>	-1492	-1045	-149	-1492	-149	-895	684
<b>Pyrene</b>	4302	-1020	4666	-1020	4666	2649	3183

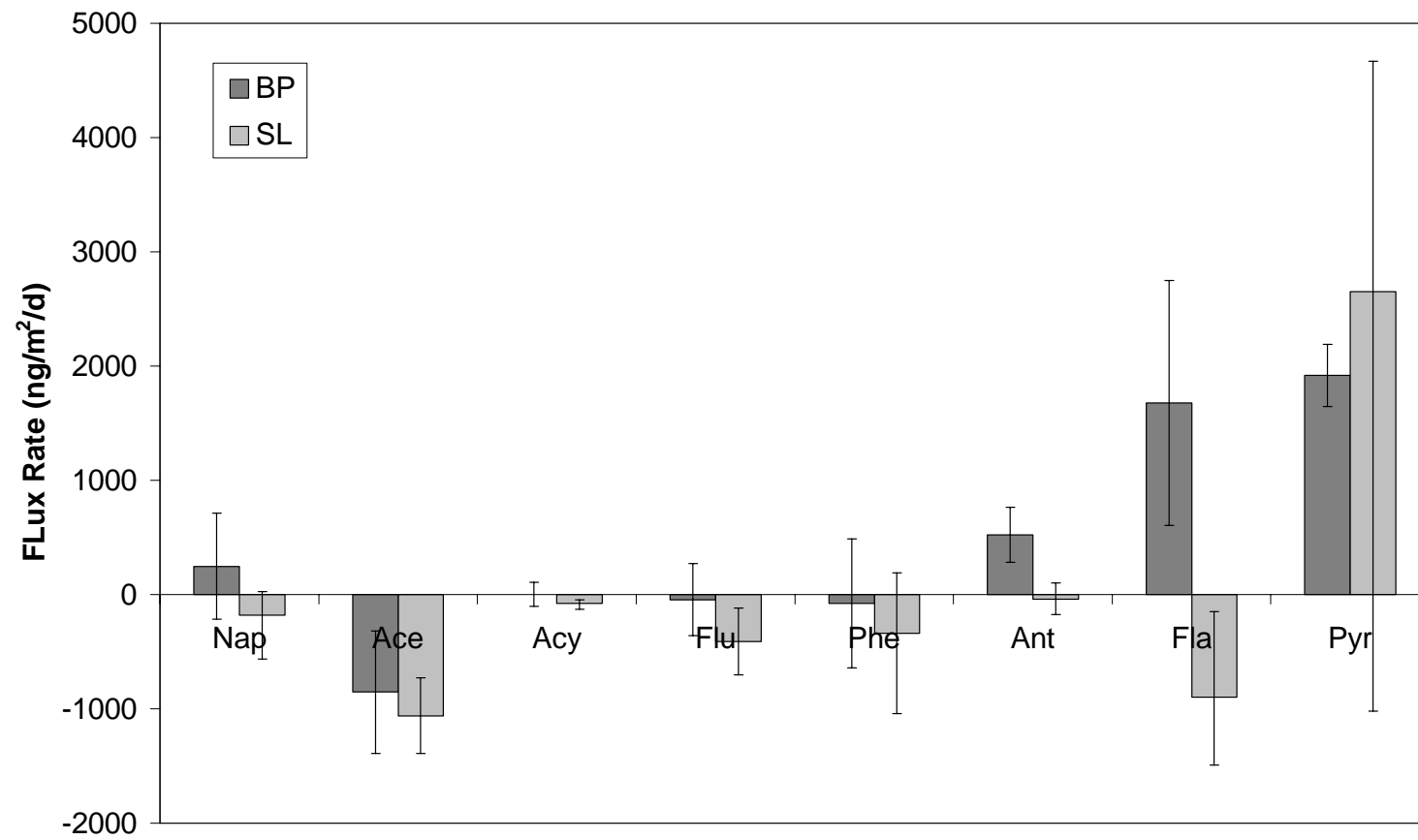


Figure 5-50. Summary plot for mean flux rates of PAHs at BP and SL. Error bars are standard deviations based on the variability of the three deployments within each area.

## **Discussion**

### **System performance**

In general, the flux deployments were successful in providing quantitative data for assessment of the PRISM diffusive flux pathway. For metals, flux rates were obtained at all six sites for all metals of interest with the exception of silver at three stations. For PAHs, the heavier molecular weight components were generally below detection limits, but flux rates were successfully quantified for a range of light to moderate molecular weight PAHs in both areas. The three station deployments within each area provided data for the assessment of localized variability. Quantification of this variability is critical in establishing bounds on the relative importance of diffusive mobility to the general contaminant fate balance in surface sediments.

### **Variability**

Variability in metal and PAH fluxes was quantified on three distinct scales in this study including variability in individual measurements, variability within a site (scale 20-100 m), and variability between sites (scale 5 km). Variability within an individual flux measurement is quantified based on the variance of the slope of the concentration with time. The variability in the slope may arise from a number of factors including actual non-linearity of the measured process, sample contamination, and analytical variability. For the BFS, assessment of this variability is evaluated based on comparison to blank chamber runs (runs with a Teflon panel in place of sediment). Based on a statistical comparison of the deployment data versus the blank, an assessment is made as to whether the flux is “detectable”. This simply means that a flux was detected by the instrument that can be distinguished from a flux when no sediment is present. This does not necessarily imply that the flux is significant from a transport or ecological perspective. By the same token, failure to detect a flux that is distinguished from the blank does not necessarily mean that the flux is insignificant, rather that with the BFS technology, we are simply not able to determine a flux rate that is quantifiable in comparison to the blank. This is parallel to, for example, the measurement of a water concentration. If the concentration is detectable, we can quantify the value, but this does not infer that it exceeds an effects threshold. Similarly if we cannot detect it, but the effects threshold is below our detection limit, we cannot rule out a potential effect. For this reason, it is important to know whether fluxes were detectable when interpreting the data here, but we continue to use the entire data set for the general analysis so that perspective can be gained on the relative importance of fluxes within the context of PRISM.

In general, we found that fluxes for the listed metal and PAH constituents were detectable in the majority of the deployments. The primary exceptions included Ag for the metals, and Acenaphthene and Fluorene for the PAHs.

Within site variability was evaluated on the basis of three deployments at stations separated by tens of meters. In general, these results indicate a fairly high degree of variability. This is expected to some degree because of the heterogeneous nature of the sediments and the geochemical and biological processes that regulate fluxes. While the variability is not surprising, it is critical that it be quantified within the context of PRISM.

Since the flux rates will be used to compare the relative importance of various processes within a general transport balance, quantification of within site variability will allow the range of possible outcomes to be explored.

Variability across the two sites (BP and SL) was evaluated on the basis that these two areas could have different transport processes that might be active or dominant. Thus comparison across sites provides insight into how well our tools can distinguish differences as we move from one environment to another.

### **Metal fluxes**

Metal flux results can be used to evaluate the general mobility of site CoCs, the relative differences among metals, the differences within a site, and the differences between the two sites. The fluxes can also be evaluated in the context of other supporting data such as oxygen and pH that may provide insight into the redox conditions at the sites.

In general, contaminant metals displayed a range of fluxes. Lowest flux rates were generally observed for Ag, Cd, and Pb (with the exception of lead at BP). Moderate fluxes were observed for As, Cu, and Ni, and highest fluxes were consistently found for Zn. This pattern is consistent with previous BFSD results from a number of harbors that also found lowest (based on means) flux rates for Ag, Cd, and Pb and highest fluxes for Zn (see Table 5-23 and Figure 5-51). The range of flux rates measured in this study is also generally consistent with the larger historical data set. For example, the flux of As at BP and SL averaged 33 and 21  $\mu\text{g}/\text{m}^2/\text{day}$  respectively compared to the historical mean of 21  $\mu\text{g}/\text{m}^2/\text{day}$ . However, the site average flux rates for Zn of 298 and 356  $\mu\text{g}/\text{m}^2/\text{day}$  at BP and SL, although consistently higher than other metals, were lower than the historical mean value of 1577  $\mu\text{g}/\text{m}^2/\text{day}$ .

Table 5-23. Statistical summary of historical flux rate measurements using the BFSD in San Diego Bay, San Francisco Bay, Pearl Harbor and Puget Sound.

	<b>As</b>	<b>Ag</b>	<b>Cd</b>	<b>Cu</b>	<b>Ni</b>	<b>Pb</b>	<b>Zn</b>
<b>Average</b>	20.6	0.36	19.3	52.5	54.3	4.68	1577
<b>St. Dev.</b>	40.3	8.14	31.6	111	41.3	16.5	3169
<b>Min.</b>	-20.9	-21.0	-3.0	-107	-3.55	-22.0	-37.3
<b>Max.</b>	98	14.7	125	304	141	39.2	14861
<b>Count</b>	18	17	27	26	26	24	26

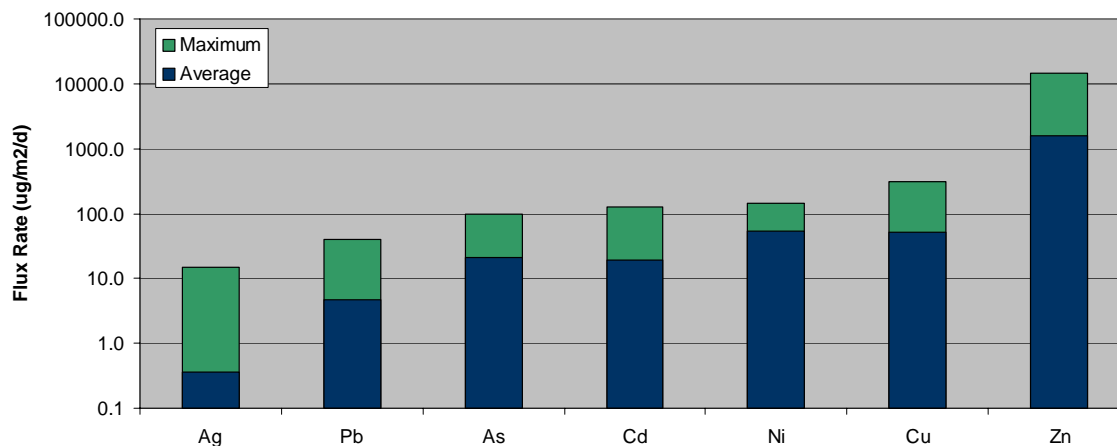


Figure 5-51. Graphical representation of the historical flux rate measurements using the BFS in San Diego Bay, San Francisco Bay, Pearl Harbor and Puget Sound.

Comparison of metal fluxes between the BP and SL areas showed a general similarity, with a few exceptions. In general, site mean metal fluxes were comparable for As, Cu and Zn. The BP site had consistently higher fluxes of Pb, while the SL site had consistently higher fluxes of Cd and Ni. Site mean fluxes for Ag were difficult to compare due to the lack of detectable levels at several stations. Direct comparison of the two areas indicates statistical differences for Cd ( $p < 0.05$ ), Pb ( $p < 0.04$ ), and Ni ( $p < 0.03$ ).

### PAH Fluxes

PAH flux results can be used to evaluate the general mobility of site CoCs, the relative differences among PAHs, the differences within a site, and the differences between the two sites. In general, PAHs displayed a range of fluxes. Lowest flux rates were generally observed for Naphthalene, Acenaphthene, Acenaphthylene, Fluorene, and Phenanthrene. Highest fluxes were observed for Anthracene, Fluoranthene, and Pyrene.

Historical data for PAH fluxes is limited. The results can be compared to results from the PRISM I deployments that were performed at Paleta Creek in San Diego Bay (Figure 5-52). From this comparison we find that the patterns of fluxes between this earlier study and the current one are similar in terms of which PAHs had fluxes and their relative magnitudes within each study, but the magnitude of the flux rates was generally higher during the PRISM II study in Pearl Harbor. The consistency in the pattern of fluxes is encouraging from the standpoint that it suggests a process oriented control.

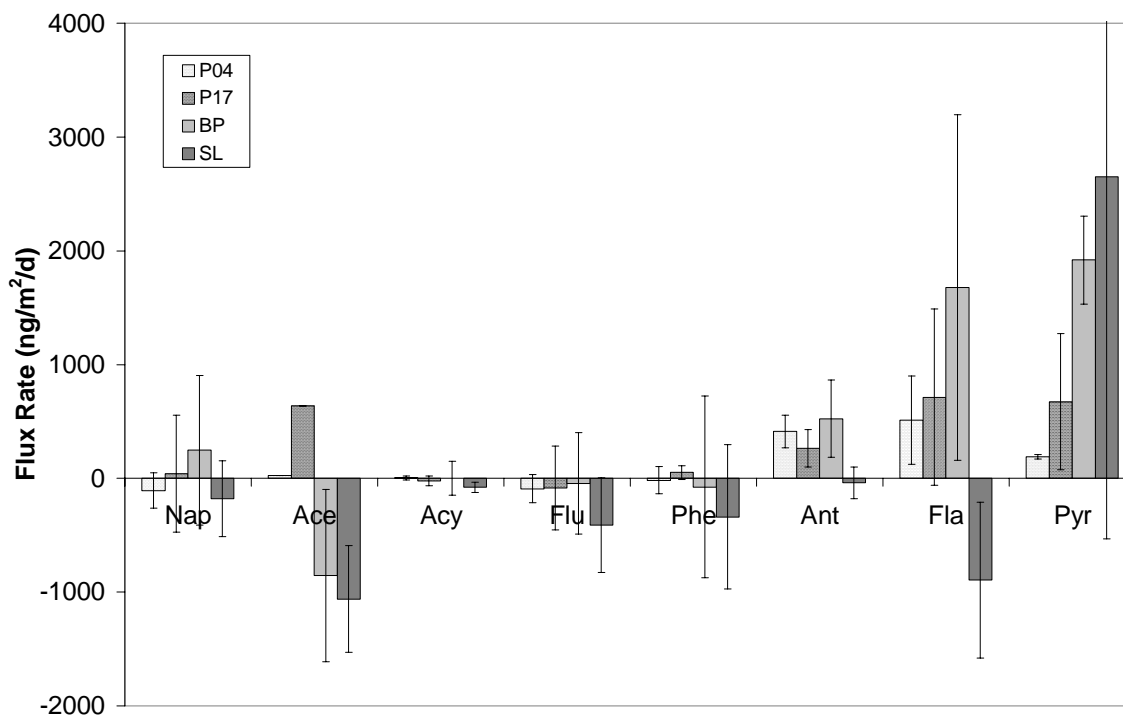


Figure 5-52. Comparison of BP and SL PAH flux rates with the PRISM I results at Paleta Creek.

Comparison of PAH fluxes between the BP and SL areas also showed some distinctive patterns. In general, site mean PAH fluxes were higher at BP compared to SL (see Figure 24). Only Pyrene had a higher mean fluxes at SL. Site mean fluxes for Acenaphthene, Fluorene and Phenanthrene were negative at both sites. Direct comparison of the two areas indicates statistical differences for Anthracene ( $p < 0.12$ ), and Fluoranthene ( $p < 0.12$ ).

### Application to PRISM

Application of the flux results to the general transport balance in PRISM is relatively straight-forward. This is because the BFSF provides direct measurement of surface fluxes that are a specific component of the PRISM indices. Thus integration of the flux results requires application of site mean fluxes to the general balance equation. In addition, evaluation of variability must be incorporated based on the replicate measurements, and the results must be interpreted within the context of quantification of individual flux rates in comparison to blanks.

Another important consideration for application of the flux results is in relation to time-scales. The flux rates are generally determined over a period of about three days. This time frame was developed to provide a good level of detection, balanced against too long of a deployment that might result in significant alterations of the chamber environment. Thus the flux chamber results are, in general, most applicable for time scales of days to weeks. This means that the results are best interpreted as providing insight into the

balance as it currently stands. However, evaluations of rate balances, as is required for PRISM, may require extrapolation of this data to longer time scales. These extrapolations must be done with care since changing conditions in redox, concentration gradients, and overlying water may alter fluxes. However, some context for this extrapolation is provided by comparison of these rates to rate measurements at a number of other harbor sites (e.g. Figure 25). These results suggest that the magnitude of these rates is not likely to change too substantially, and if the flux currently constitutes a significant pathway, it probably will continue to do so for some time into the future.

Finally, it should be pointed out that our initial attempt to quantify bioinhibited flux rates was largely unsuccessful. Two factors played into this failure, the primary issue being the inability to drive the oxygen levels completely to zero over the deployment time. The second factor was that in several cases, it appeared that silica fluxes were large enough to quench flux rates, probably as a result of a decrease in the gradient between the porewater and the chamber water as silica accumulated in the chamber. This outcome confounds the bioinhibited results because it causes the same type of response, but for a different reason. Both of these problems can be attributed to some degree to the time of year the deployments were made. While historically, field deployments have generally been conducted during warmer water periods in the spring, fall and summer, these deployments were conducted in mid winter. Cold water conditions during this period have two effects. The first is to reduce microbial activity, which in turn reduces oxygen uptake by the sediments. The second effect is that cold water enhances the dissolution of silica, thus leading to higher silica fluxes. Future efforts to assess bioinhibited flux rates should attempt to account for these factors.

## **Summary**

Flux rates were successfully quantified at three stations each within two sites in Pearl Harbor, Hawaii. Fluxes were measured for a number of metal and PAH constituents. Mean fluxes and the variability of these fluxes were estimated based on the replicate deployments at each site. Patterns of metal fluxes were similar to historical deployments, with lowest fluxes generally for Ag, Cd, and Pb, moderate fluxes for Cu, Ni and As, and highest fluxes for Zn. For PAHs, highest fluxes were generally observed for Anthracene, Flouranthene, and Pyrene. PAH fluxes during this study were somewhat higher than previously observed at Paleta Creek. Fluxes were distinguishable from blanks for the majority of deployments and constituents. Highest fluxes for both metals and PAHs were generally detected at BP versus SL. Fluxes for several metals and PAHs were distinguishable between sites.



### **5.3 ULTRASONIC SEEPAGE METER MEASUREMENTS**

#### **Introduction**

As part of the Pathway Ranking for In-place Sediment Management (PRISM) project, the Marine Program of Cornell Cooperative Extension assisted in the development, testing and field deployment of systems for sediment and contaminant advection potential. In a coordinated effort with other scientists, Cornell utilized their ultrasonic groundwater seepage meter (Paulsen et al., 2001) to quantify submarine groundwater discharge (SGD) into Pearl Harbor (Southeast loch and Bishop Pt. sites) as a means of monitoring contaminant transport in coastal environments.

The objectives of this project were to: (1) review existing site data reports to support the design of appropriate field demonstrations; and (2) deploy instrumentation, and collect and analyze samples at the second demonstration site (Pearl Harbor). Deployments and sampling included the preparation of instruments and sampling equipment, the physical installation of the instruments and collection of the samples, and the retrieval of the instruments described above.

#### **Background**

The principle aquifer system on Oahu is divided into three major parts: the dike area, the volcanic rock aquifer and the cap rock area. The seven major groundwater areas are depicted below in Figure 5-53. The Pearl Harbor study site is located in the Southern Oahu groundwater area.

The geologic make up of the Southern Oahu area is comprised of sedimentary deposit known as the cap rock and the volcanic rock aquifer below. The volcanic rock aquifer is a confined aquifer with a high porosity, hydraulic conductivities that can be as high as 1000 ft/d. The Cap rock aquifer overlays the volcanic aquifer and is a sedimentary aquifer comprised of marine deposits, limestone and weathered volcanic rock. Figure 5-54 is a generalized cross-section depicting the features of the aquifer beneath the Pearl Harbor study area.

The cross-section reveals that an extensive aquifer system exists below the site and is recharged by significant rainfall inland (40 to 120 inches per year). The large recharge will produce significant hydraulic gradients that in turn will drive groundwater to the shoreline and ultimately up through the cap rock and into the Lochs or other surface waters. Figure 5-53 also defines the flow paths, and location of the groundwater divides.

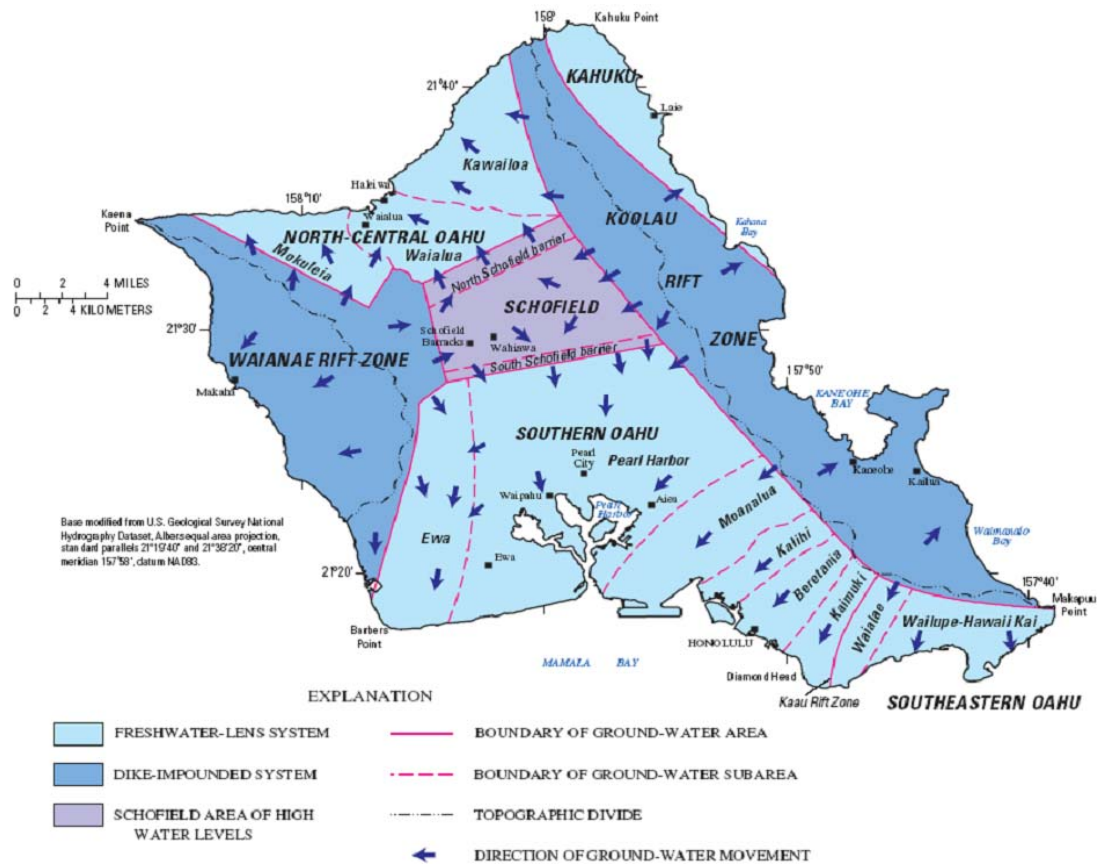


Figure 5-53. Groundwater areas, flow paths and divides on the island of Oahu.

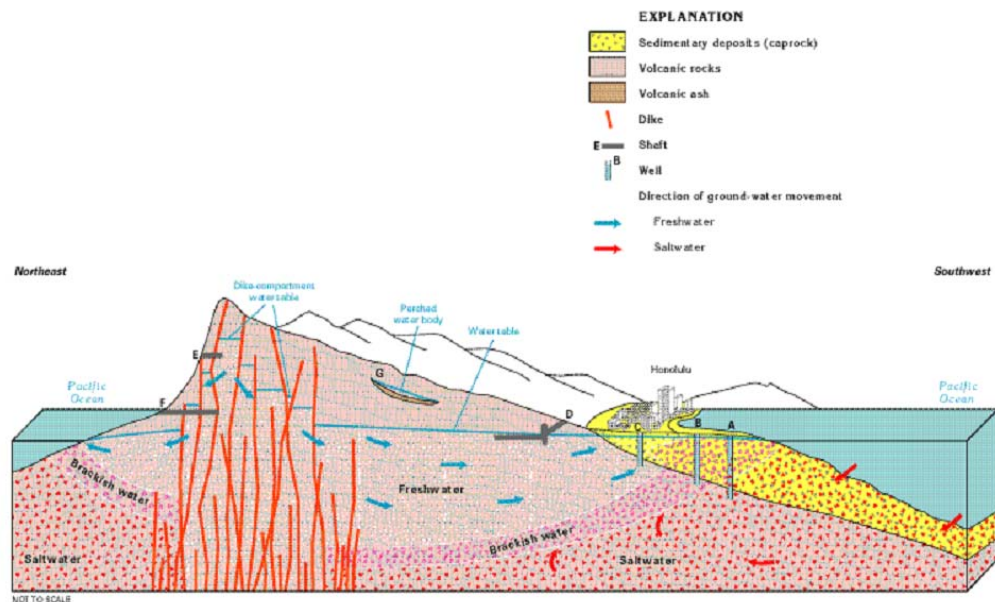


Figure 5-54- Cross-Section of the Southern Oahu Aquifer

## Methods

Deployments of seepage meters were made at two locations, Southeast Loch and Bishop Point (Figure 5-55). Both sites are areas that have the potential for sub-marine groundwater discharge. Deployments were made at three locations at each study site. Additional support data (pore water temp, conductivity and head) were collected at each site to verify and map of the magnitude of sub marine groundwater discharge at each site.

### Conductivity Probes

To identify potential areas where groundwater is entering the surface water, we employed a simple direct-push system equipped with a conductivity probes. Contrast in conductivity between surface water and groundwater were used to determine likely areas of groundwater impingement. The conductivity sensor utilizes a standard GeoProbe Wenner-type resistance cell. The probe is configured with two pairs of stainless steel electrodes, the outer pair through which a known current is imposed, and the inner pair through which the voltage is monitored. Both pairs of electrodes are coupled through an underwater connector and cable to a standard, Geoprobe model FC4000 deck unit which controls the outer electrode pair current, monitors the inner electrode pair voltage, and records the corresponding raw conductivity signal to a computer. The conductivity signal varies primarily as a function of changes in salinity, and secondarily as a function of clay content and porosity. Areas of likely groundwater seepage are generally associated with low conductivity, either as a result of low salinity, low clay content (high permeability), or both.

### Seepage Meters

Specific discharge measurements for the Pearl Harbor sites were collected using the time transient ultrasonic groundwater seepage meter introduced by Paulsen et al (2001). The seepage meter uses two piezoelectric transducers to continuously measure the travel times of ultrasonic waves. As water enters the flow tube, it passes through the ultrasonic beam path (Figure 5-56). The ultrasonic signal that travels with the flow will have a shorter travel time than the signal traveling against flow. The perturbation of travel time is directly proportional to the velocity of flow in the tube.

To collect groundwater seepage across the sediment water interface, an angled funnel with a square cross section of  $0.209 \text{ m}^2$  is inserted into the sediment using a 5-lb rubber mallet when necessary. As with the Lee (1977) method, the funnel is equipped with a nozzle that allows water to escape. Attached to the nozzle of the funnel is 44-cm of tygon tubing (1.8 cm I.D.) that leads to the flow tube. The angle of the collection funnel was chosen such that the end of the funnel with the outflow tubing is slightly higher than the back end, thus allowing air to escape. The flow tube is connected to a data logger that records both incremental and cumulative discharge simultaneously (Figure 5-57). The data logger is capable of recording in time increments ranging from 1 second to 24 hours. The data logger is also able to detect reversals of flow such as a negative groundwater flux in which the overlying surface water is recharging the seepage zone. For field deployment in Pearl Harbor, the data logger and a back-up battery were housed in a buoy that was anchored to the harbor bottom. The battery life of the logger itself is

approximately 5 hours, while the back-up battery (marine / car battery) has a life span of approximately 120 hours.

The ultrasonic seepage meter records specific discharge in cm<sup>3</sup>/s. Therefore, to obtain the specific discharge through the capture area over the sediment-water interface:

$$q = \left( \frac{Q}{A_t} \right) \left( \frac{A_t}{A_f} \right) = \frac{Q}{A_f}$$

where q = specific discharge (cm/s)

Q = discharge (cm<sup>3</sup>/s);

A<sub>t</sub> = area of flow tube (cm<sup>2</sup>)

A<sub>f</sub> = area of the funnel (cm<sup>2</sup>).

During the Pearl Harbor study, we also employed the prototype versions of the UltraSeep. The UltraSeep system is an integrated seepage meter and water sampling system for quantifying discharge rates and chemical loading from groundwater flow to coastal waters. Traditional seepage technology was modified and improved to include automated multiple sample collection and continuous flow detection with ultrasonic flow meters. The resultant instrument, the UltraSeep, makes direct measurements of advective flux and contaminant concentration at a particular location (Chadwick et al., 2003). The data produced are time series, over tidal cycles, of groundwater flow, contaminant concentration, and associated sensor data. This allows an accurate determination of the presence or absence of groundwater flow and associated contaminant flux from a terrestrial site into a bay or estuary (Figure 5-58).

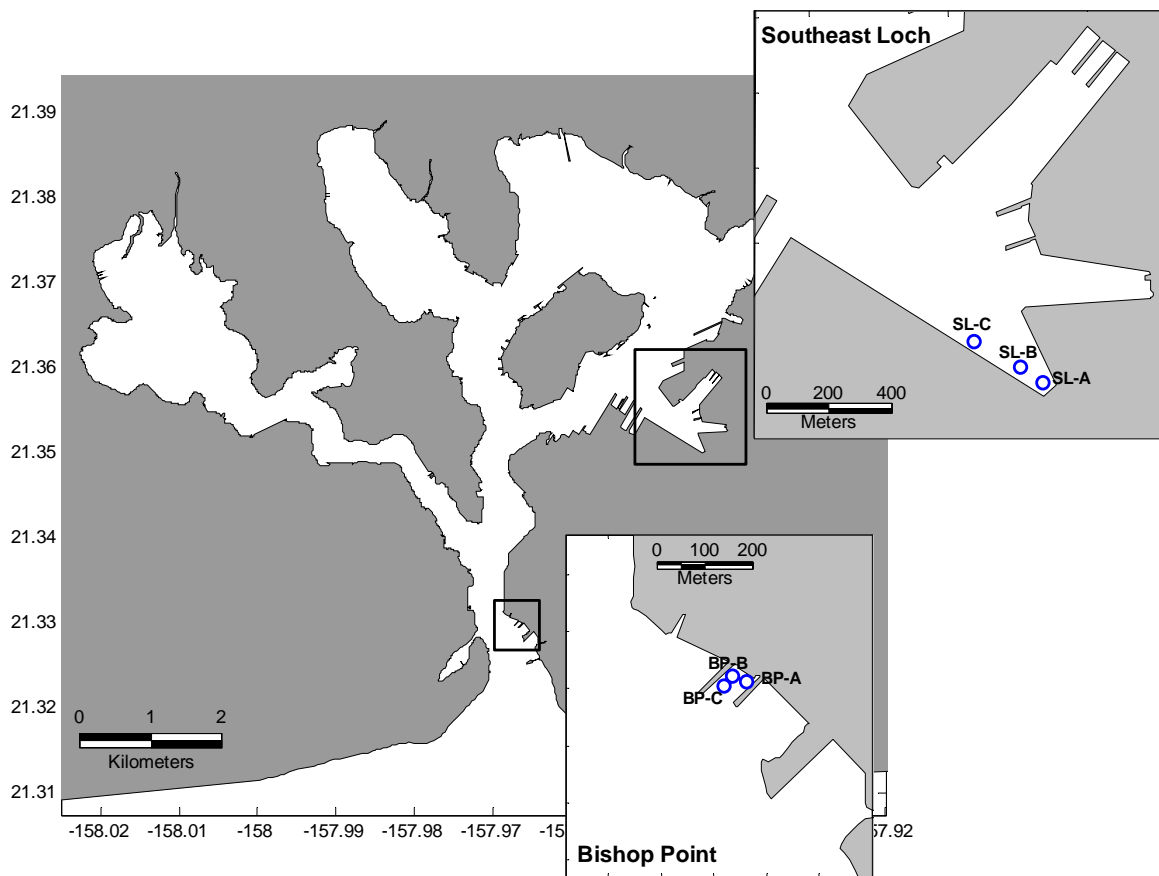


Figure 5-55- Deployment Locations

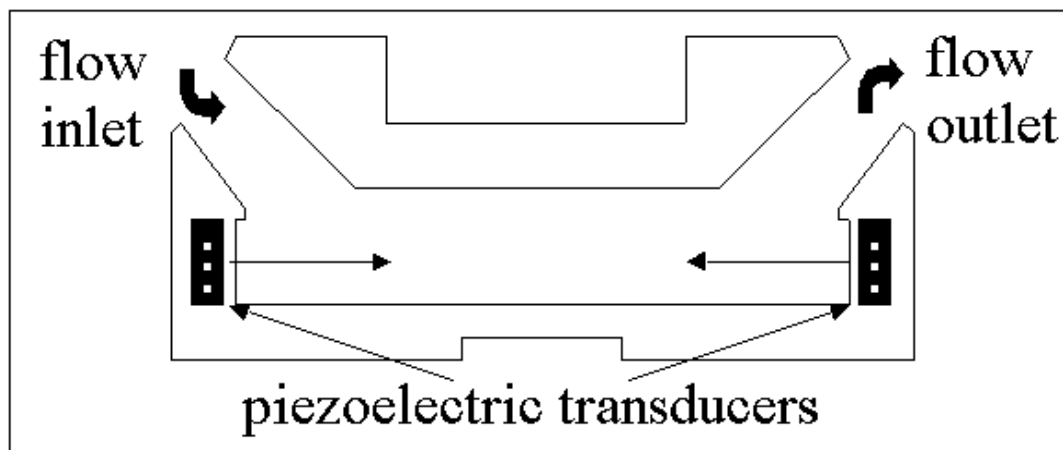


Figure 5-56. Cross section of the ultrasonic seepage meter flow tube showing the difference in signal arrival times with flow (from Paulsen et al, 2001).

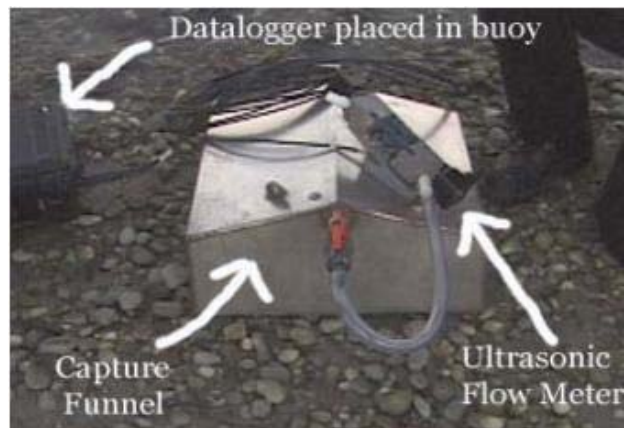
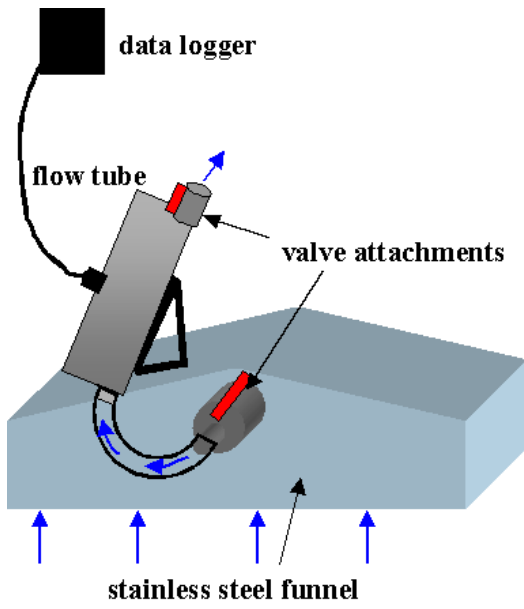


Figure 5-57. Schematic and photo of the ultrasonic seepage meter.



Figure 5-58. Component view of the prototype UltraSeep showing the water sampling and control units, battery housing, flow meter, data logger and funnel.

## Results

Data acquired from Pearl Harbor from sites Southeast Loch (UltraSeep A at SLA, UltraSeep B at SLB, ultrasonic buoy at SLC and Bishop Pt. (ultrasonic buoy at BPA, UltraSeep A at BPB, UltraSeep B at PBC) were analyzed and average specific discharge rates were calculated for a full 24-hour tidal period at each station. Replicate measurements were obtained at stations BPB, BPC, and SLC. Water samples were collected by the UltraSeep B meter at a subset of the stations. The water sampling system on the UltraSeep A meter malfunctioned so no samples were obtained with this meter. Two conductivity transect near stations BPA, BPB, and BPC were also taken.

## Bishop Point Deployments

Conductivity profiles were collected along two transects in the Bishop Point study area. The first transect extended ~90 ft into the harbor from the quay wall and crossed the location of the seepage meter station at BPA (Transect 1). The second transect also extended about 150 ft into the harbor from the quay wall and crossed the location of the seepage meter stations at BPB and BPC (Transect 2). Conductivity was measured at 0.5 ft and 2.0 ft below the sediment surface along each transect. Results are shown in Figure 5-59 and Figure 5-60. Both transects showed a generally decreasing trend in conductivity with distance from the quay wall. Along transect 1, the conductivity decreased from the quay wall out to the 30 ft station, then increased somewhat at the 45 ft station, and decreased again for the remaining outer stations out to 90 ft. The gradient was most apparent at the 2 ft push depth, although a similar but weaker gradient was also observed at the 0.5 ft push depth. Along Transect 2, the conductivity increased slightly out to the 45 ft station, then decreased sharply out to the 75 ft station, and remained low out to the 110 ft station. Again, the trend was strongest in the 2 ft push with a similar but weaker trend in the 0.5 ft push. The horizontal gradients observed in both transects suggest that the strongest potential in groundwater discharge was at distances >45 ft from the quay wall. This is consistent with the findings from the seepage meters (see below).

Seepage meter were deployed at three stations in Bishop Point site. Two stations were located in close proximity of the quay wall (stations BPA and BPB) and one station was located approximately 150 ft offshore (station BPC). Seepage measurements at stations BPA and BPB (Figure 5-61, Figure 5-62 and Figure 5-63) revealed little groundwater discharge was present. Station BPA had a mean specific discharge rate of 0.7 cm/d and station BPB had a mean specific discharge rate of 0.2 and -0.5 cm/d for the replicate measurements (Table 5-24). Specific discharge at BPA showed a weak tidal signal with a tendency toward more positive flow during low tide. No significant tidal fluctuations were observed in the two replicates at BPB. The close proximity of these stations to the quay wall potentially cuts them off from the upland groundwater gradient. It is likely that the quay wall deflects the seepage area further offshore as indicated in the results for station BPC (Figure 5-64 and Figure 5-65). Specific discharge measurements at station BPC revealed advective flow with mean specific discharge rates of 9.5 and 5.6 cm/d for the two replicate deployments. Both stations exhibited some tidal fluctuation, with maximum discharge occurring at or just following high water.



### Southeast Loch Deployments

Seepage measurements were made at three stations in Southeast Loch. The stations were located in a linear fashion starting from the bulkhead area near the head of the Loch (SLA), and heading northwestward along Bravo Pier (SLB, SLC). All stations in Southeast Loch revealed the presence of groundwater discharge. Station SLA had a mean specific discharge of 1.7 cm/d (Figure 5-66) with somewhat higher discharge rates during low water. Station SLB had a mean specific discharge of 2.2 cm/d (Figure 5-67), and was characterized by periodic bursts of stronger flow for periods ranging from about 1-3 hours. Based on SPI profiling and time-lapse images, it is suspected that these bursts may be associated with biological irrigation by the burrowing shrimp *Callinassa spec.* Station SLC had the strongest discharge with mean specific discharge rates of 8.4 and 3.8 cm/d for the replicate deployments (Figure 5-68 and Figure 5-69).

Table 5-24. Summary of specific discharge rates at the Pearl Harbor PRISM stations.

Station	Specific Discharge (cm/d)					
	Replicate 1			Replicate 2		
	Min	Max	Mean	Min	Max	Mean
BPA	-2.3	2.7	0.7	-	-	-
BPB	-0.3	0.5	0.2	-0.7	-0.1	-0.5
BPC	7.2	13.1	9.5	3.8	7.6	5.6
SLA	-0.7	4.4	1.7	-	-	-
SLB	0.5	6.1	2.2	-	-	-
SLC	7.9	9.3	8.4	1.6	4.9	3.8



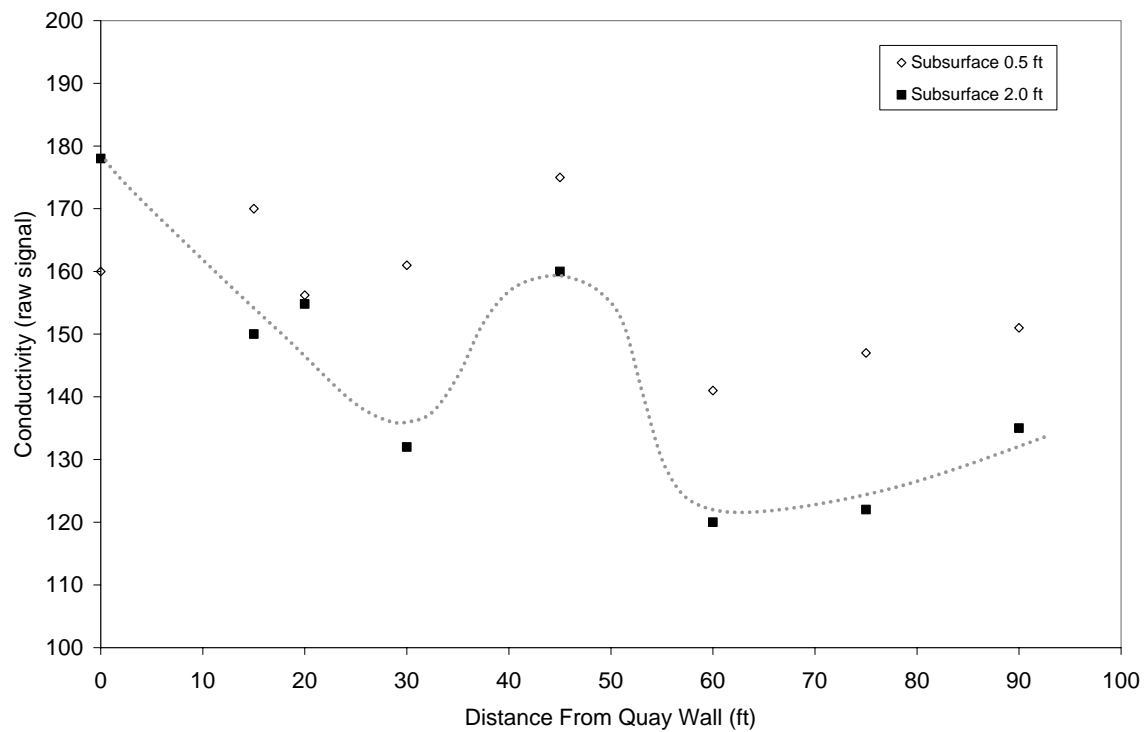


Figure 5-59. Conductivity transect 1 at Bishop Point.

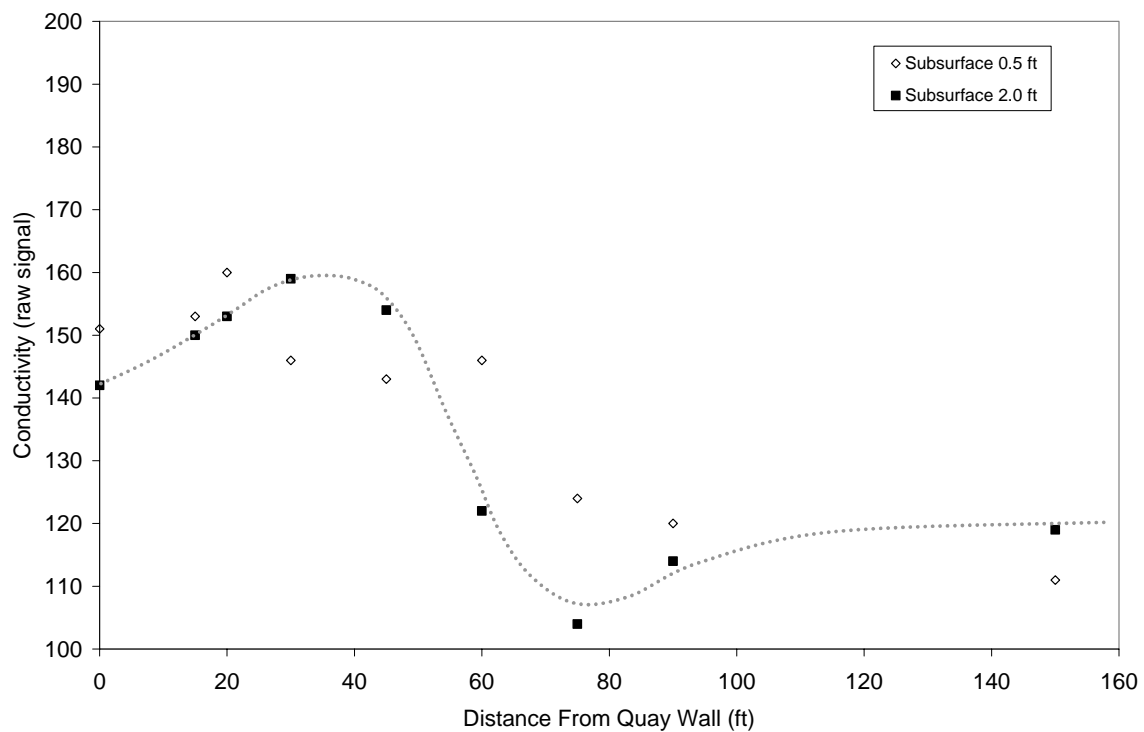


Figure 5-60. Conductivity transect 2 at Bishop Point.

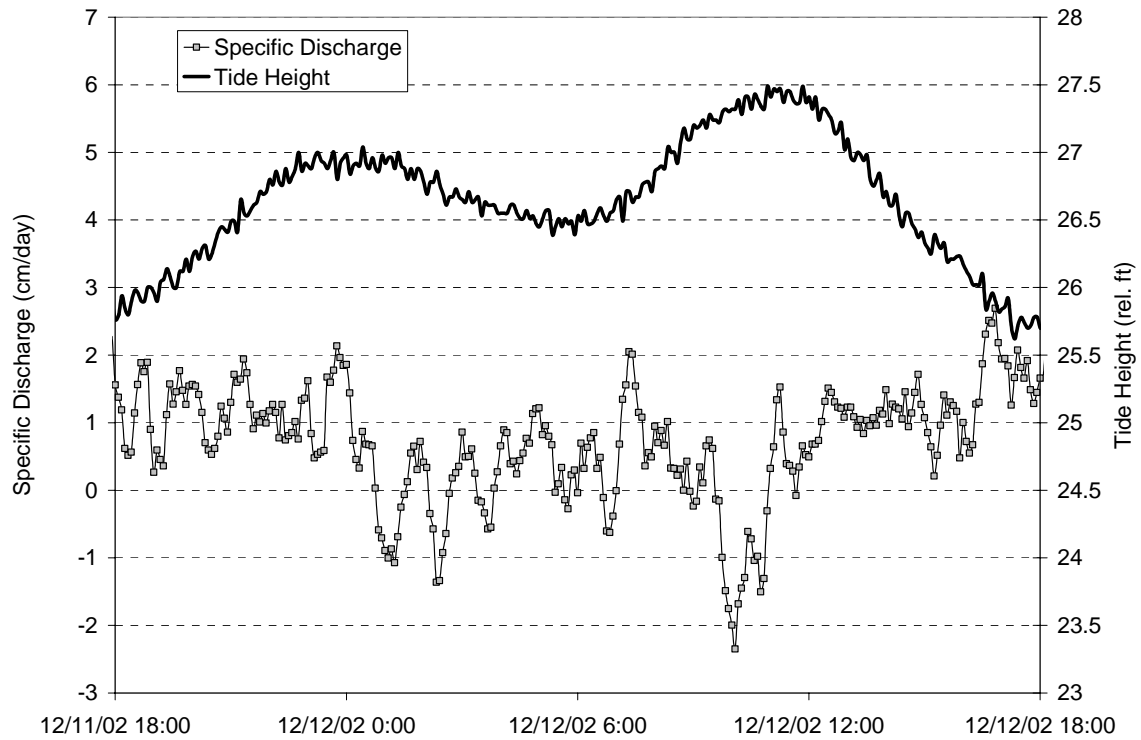


Figure 5-61. Specific discharge and tidal height at BPA1.

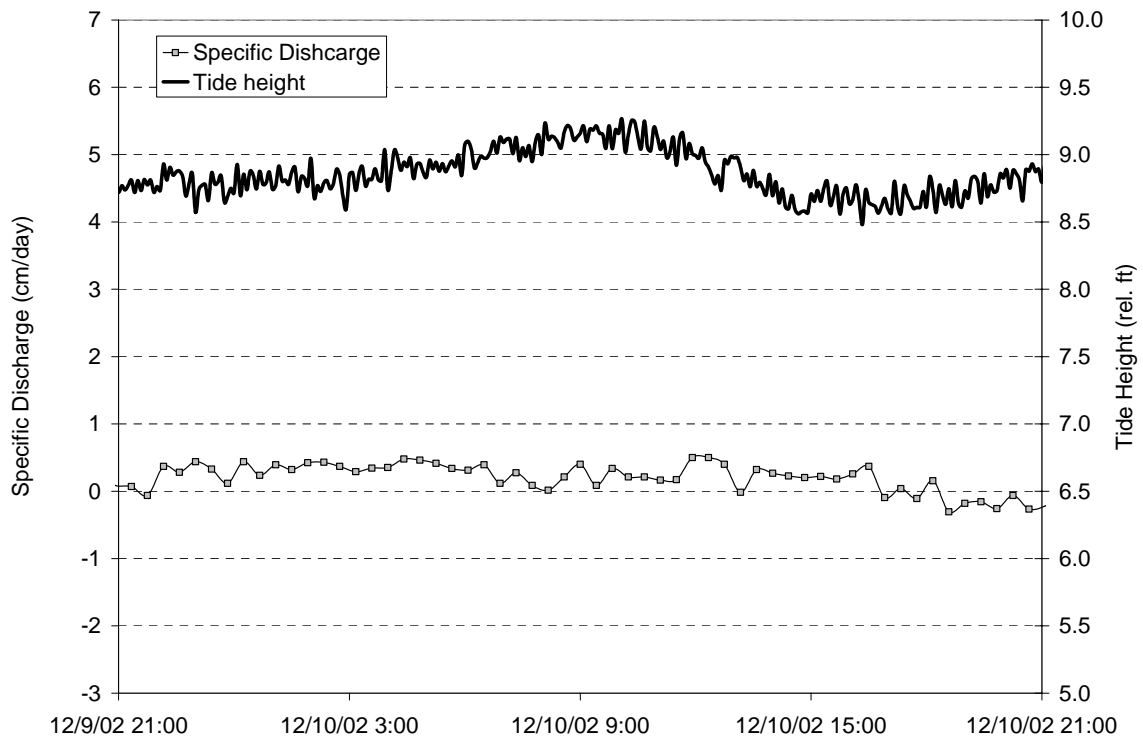


Figure 5-62. Specific discharge and tidal height at BPB1.

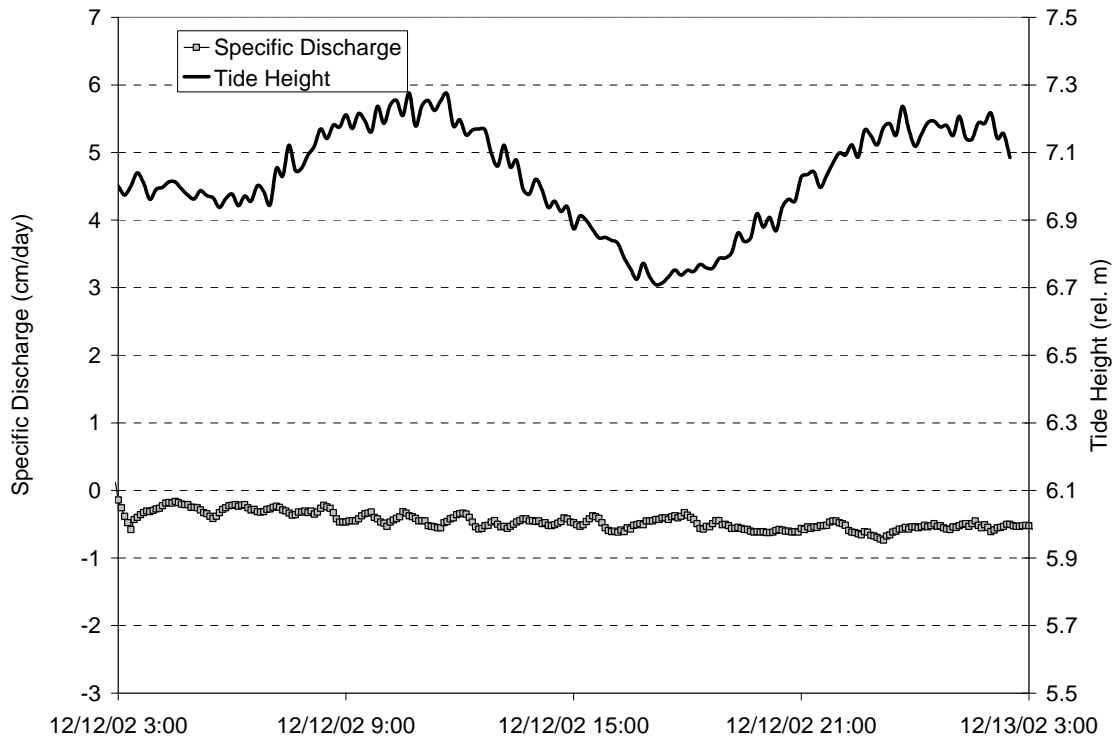


Figure 5-63. Specific discharge and tidal height at BPB2.

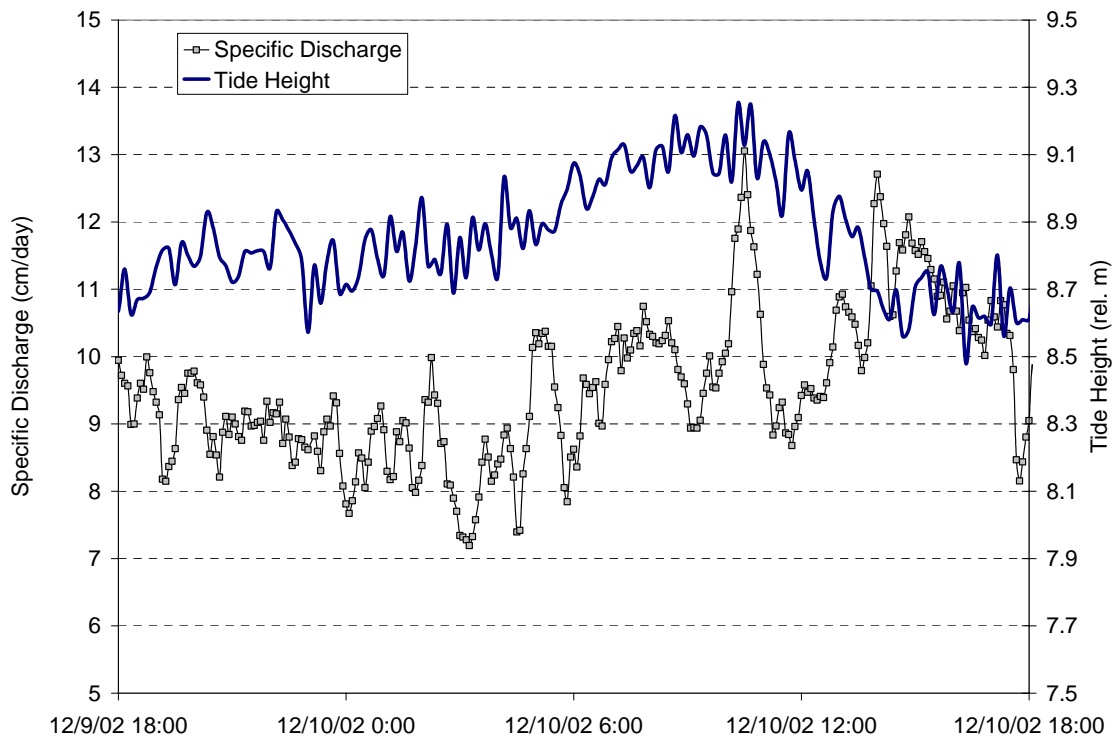


Figure 5-64. Specific discharge and tidal height at BPC1.

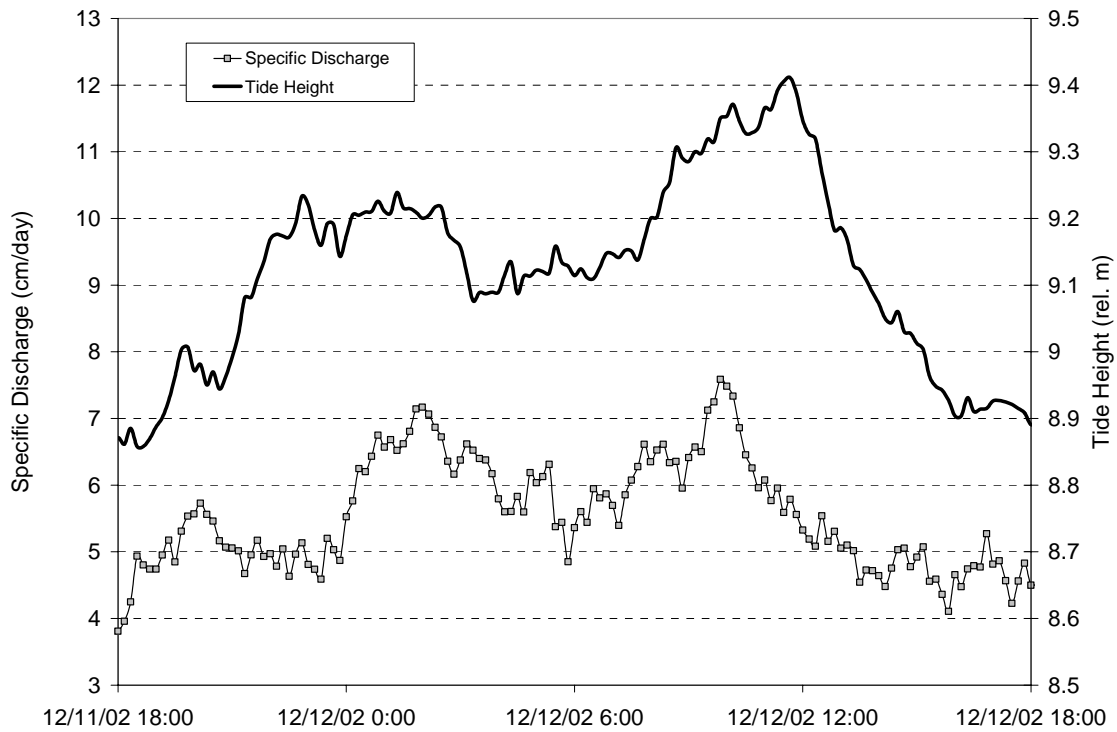


Figure 5-65. Specific discharge and tidal height at BPC2.

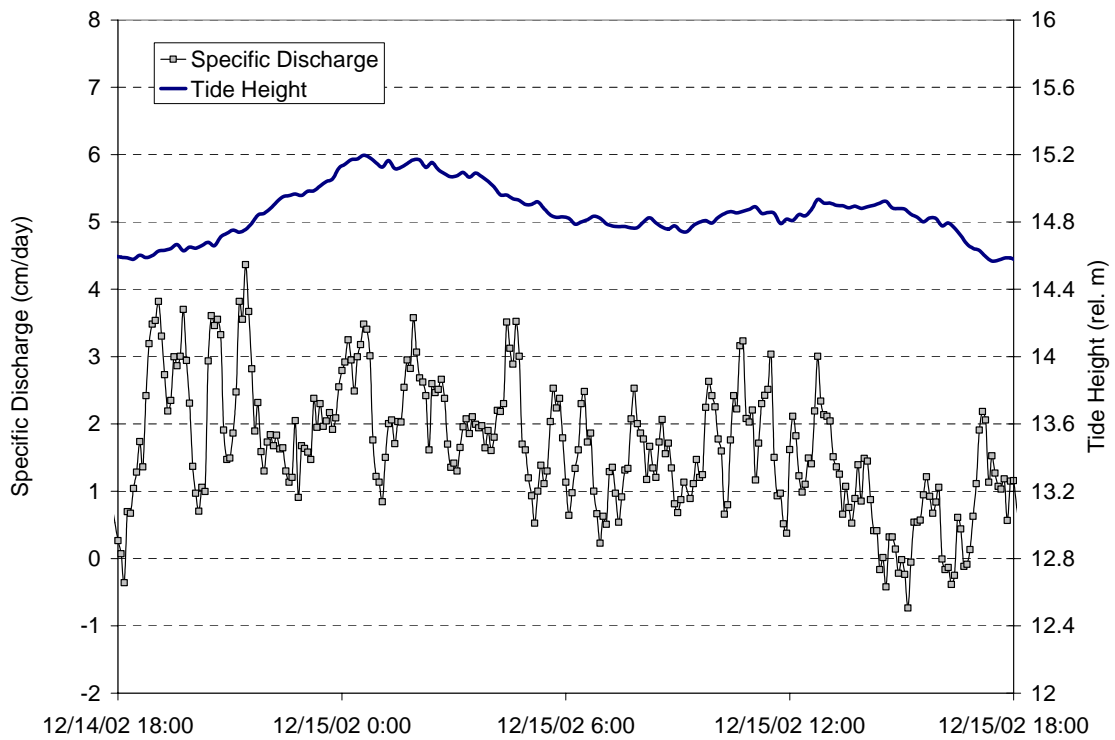


Figure 5-66. Specific discharge and tidal height at SLA1.

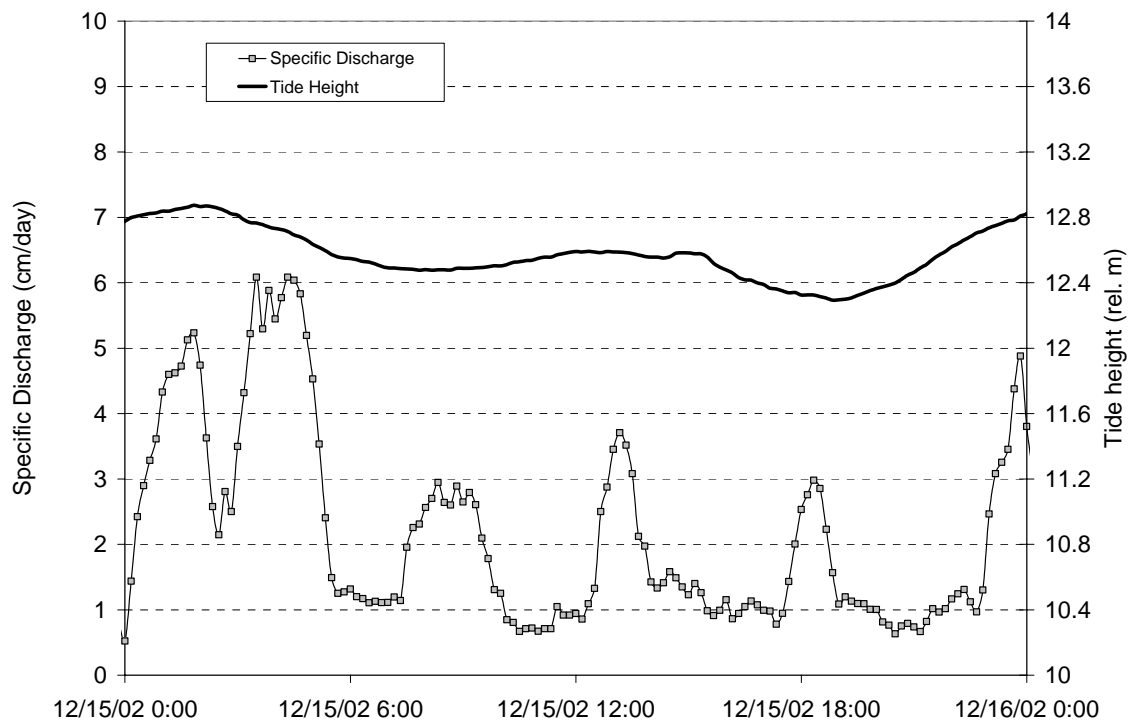


Figure 5-67. Specific discharge and tidal height at SLB1.

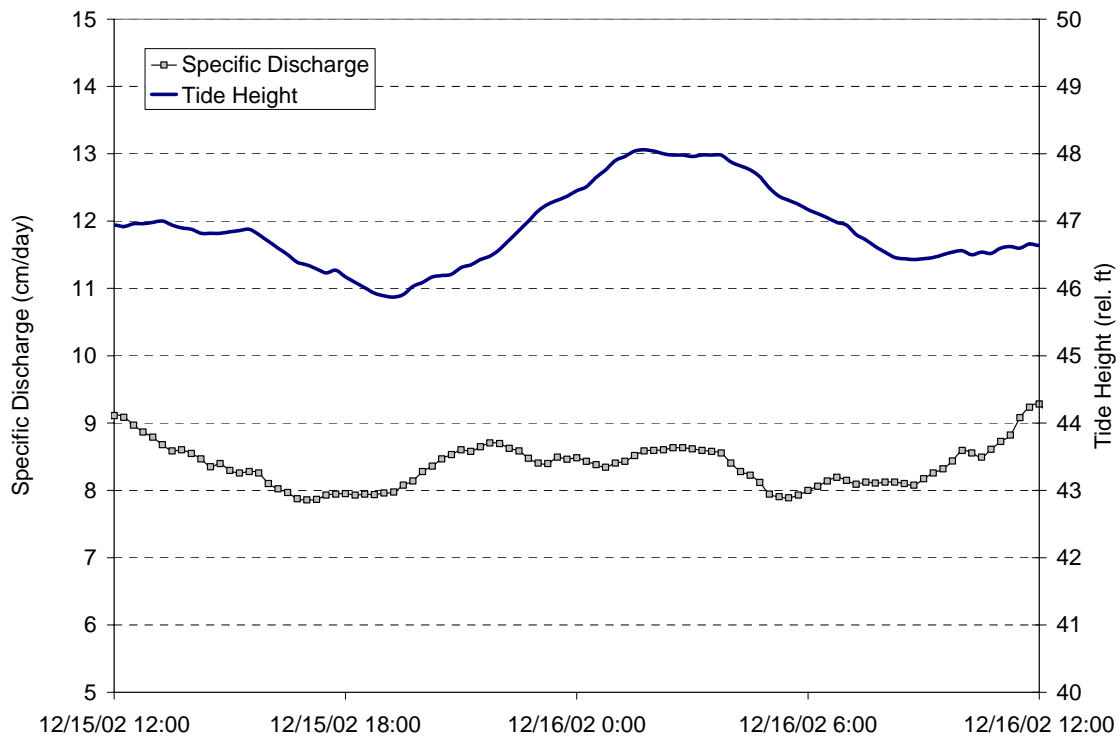


Figure 5-68. Specific discharge and tidal height at SLC1.

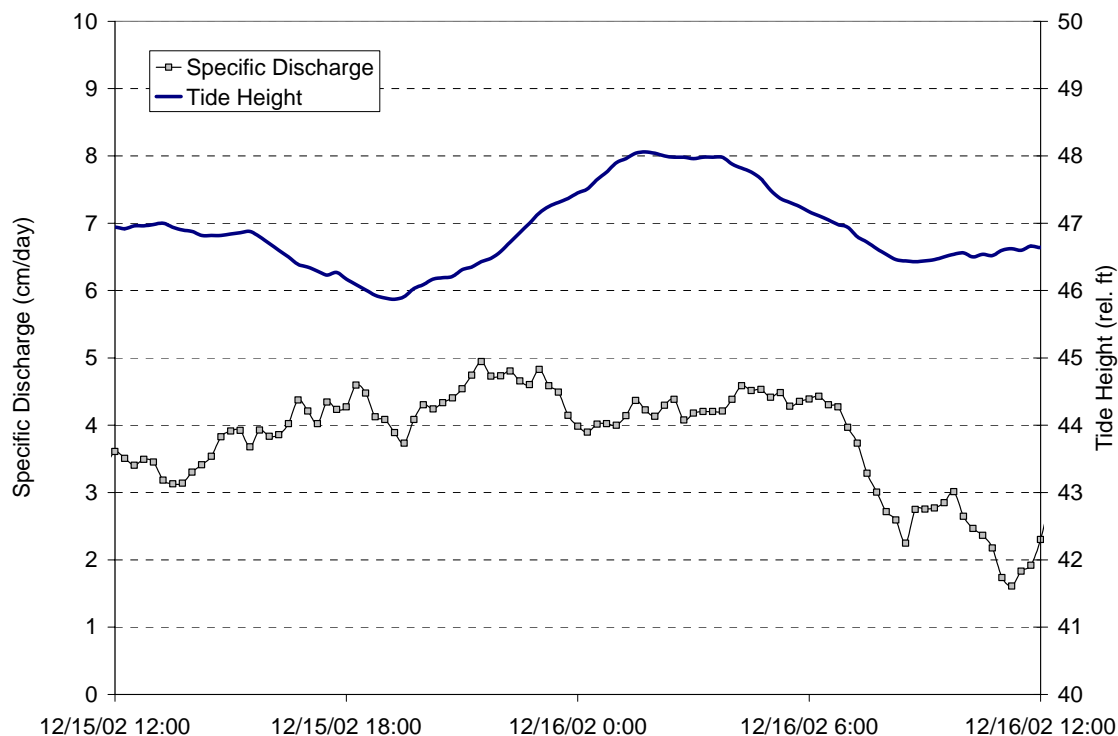


Figure 5-69. Specific discharge and tidal height at SLC2.

## Summary

The goal of the advective component of PRISM was to quantify specific discharge rates at sites BP and SL in Pearl Harbor. This was accomplished based on deployment of ultrasonic seepage meters at each of the sites. Measured seepage rates were used to determine daily average discharge rates ranging from  $-0.5$  to  $9.5$  cm/d for Bishop Point. Conductivity transects and ultrasonic seepage meter data both indicate that the majority of the discharge is occurring away from the quay wall, presumably due to deflection of the groundwater flow around the sub-surface structure of the quay wall. Replicate measures at the same stations within the site gave similar results.

For Southeast Loch, average discharge rates were positive throughout the site, with rates ranging from  $1.7$  to  $8.4$  cm/d. There was some evidence of biological irrigation in the seepage time-series at station SLB. Replicate measures at the same stations within the site gave similar results.

## 5.4 COMPOSITED POREWATER AND OVERLYING SEAWATER ANALYSES

### Methods

While detailed porewater profiles were generated for some of the geochemically important constituents, using either microelectrodes or high-resolution core sections, these methods do not have either the specificity or the sensitivity for a number of the COPCs under consideration. However, in order to calculate fluxes of various constituents using the developed equations, porewater and surface water concentrations of these COPCs were required. Cores were retrieved from the multicorer, and brought to the surface. For seawater analyses, overlying water from the cores was carefully siphoned off, and such surface waters from 12 replicate multicores from each site were composited and sent to Battelle laboratories for analyses. For porewater analyses, cores were sliced at the depth assigned as H based upon SPI interpretations. Below the H level, a separate slice was made to determine the H- porewater chemistry. Sediments were then centrifuged in the laboratory, and porewaters were separated. The porewaters from the H and H- slices from 12 replicate multicores from each site were composited and sent to Battelle laboratories for analyses. The remaining sediments were then composited, subsampled, and sent to various laboratories for analysis, as described in the following sections.

### Results and Discussion for PAHs and Metals in Porewaters and Overlying Seawater

Table 5-25 shows the means and standard deviations for PAHs and metals for porewaters and seawater from each stratum.

Figure 5-70 - Figure 5-74 below show the PAH levels and distributions measured in porewaters (H and H-) and seawaters sampled at the three replicate sites at BP and SL. When all the samples are plotted together (Figure 5-70), SL porewater values dominate. Figure 5-71 shows all the BP dissolved PAHs in seawater and H and H- porewater: Porewater PAH levels are comparable to or higher than are seawater levels. Of note are the relatively high concentrations of the lighter PAHs in H porewaters, when compared to the H- values. In contrast, levels of the heavier PAHs are comparable in H and H- porewaters. Figure 5-72 shows SL dissolved PAHs in seawater and H and H- porewaters. Porewater PAH levels are comparable to or higher than are seawater levels. Note that while the patterns are similar in all PW samples, concentrations of PW PAHs for both H and H- are significantly higher than are other values. Means and standard deviations of the seawater and porewater values for BP and SL can be seen in Figure 5-73 and Figure 5-74, respectively.

Figure 5-75 - Figure 5-83 show dissolved metals in BP and SL porewater and seawater composites. Note that the scales differ from graph to graph and site to site. Figure 5-82 and Figure 5-83 compare the porewater concentrations measured for H and H- composites with those reported by Gieskes et al (this report) for higher resolution slices. For the most part, there is remarkable agreement between the two measures. It should be

noted that the composites tend to underestimate the Mn maxima, however, but generally agree with the Mn concentrations measured in the lower part of the H section. With the exception of the deepest BPC 8 sample, Cu measured in BPB1 and BPC 8 are considerably lower than those measured in the H and H- composites. Fine-scale porewater measurements can be quite variable, since burrows, bioturbation and other processes can cause heterogeneity at every scale. However, the high Cu concentration observed in the deep sample in BPC 8 sample suggests that the high values observed in the H and H- composites might represent some real, localized peaks.





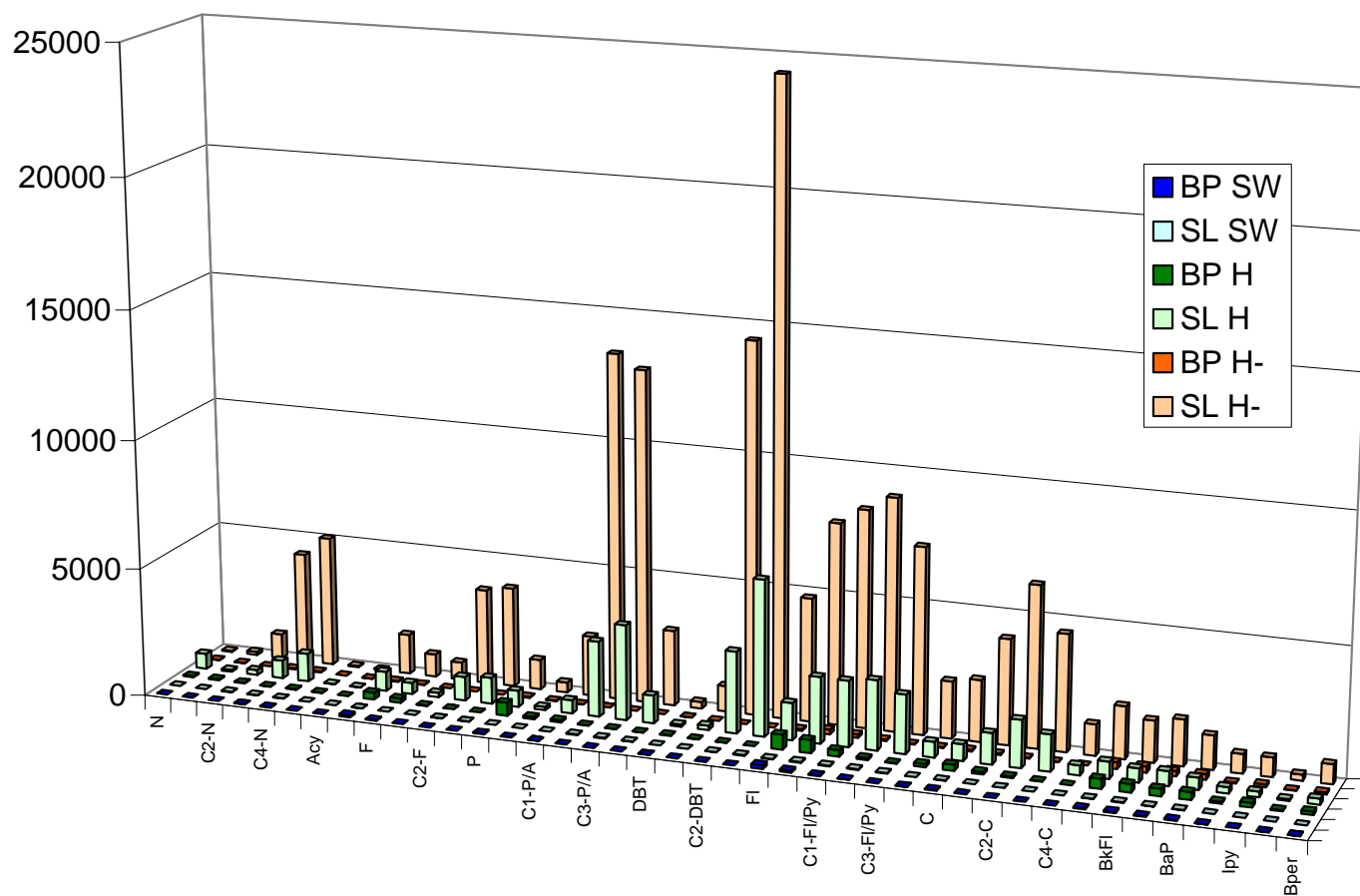


Figure 5-70. Dissolved PAHs in BP and SL seawater and H and H- porewater: Porewater PAH levels are comparable to or higher than are seawater levels. Figure is dominated by SL porewater values, which are considerably higher than are SW values or BP porewater values. Concentrations in ng/L.



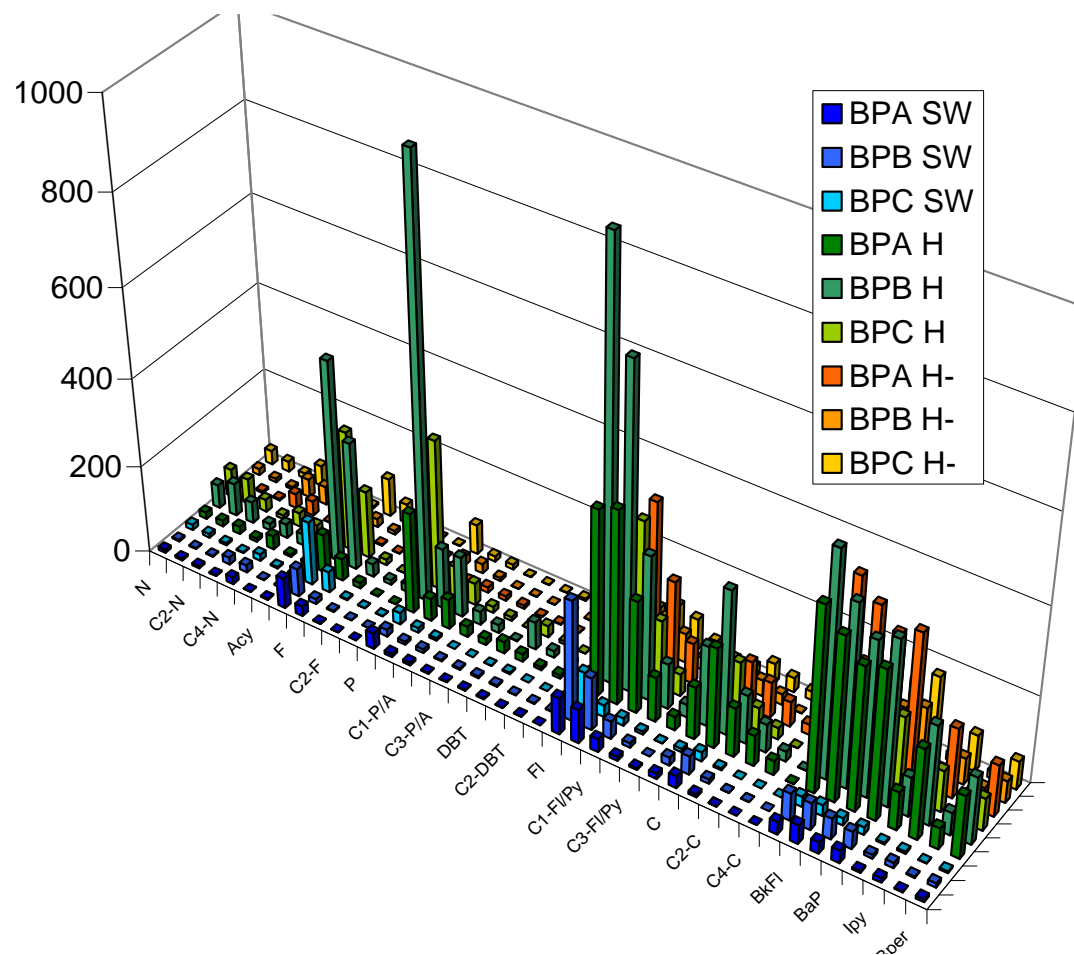


Figure 5-71. BP dissolved PAHs in seawater and H and H- porewater: Porewater PAH levels are comparable to or higher than are seawater levels. Note the relatively high concentrations of the lighter PAHs in H vs H- porewater. Concentrations in ng/L.

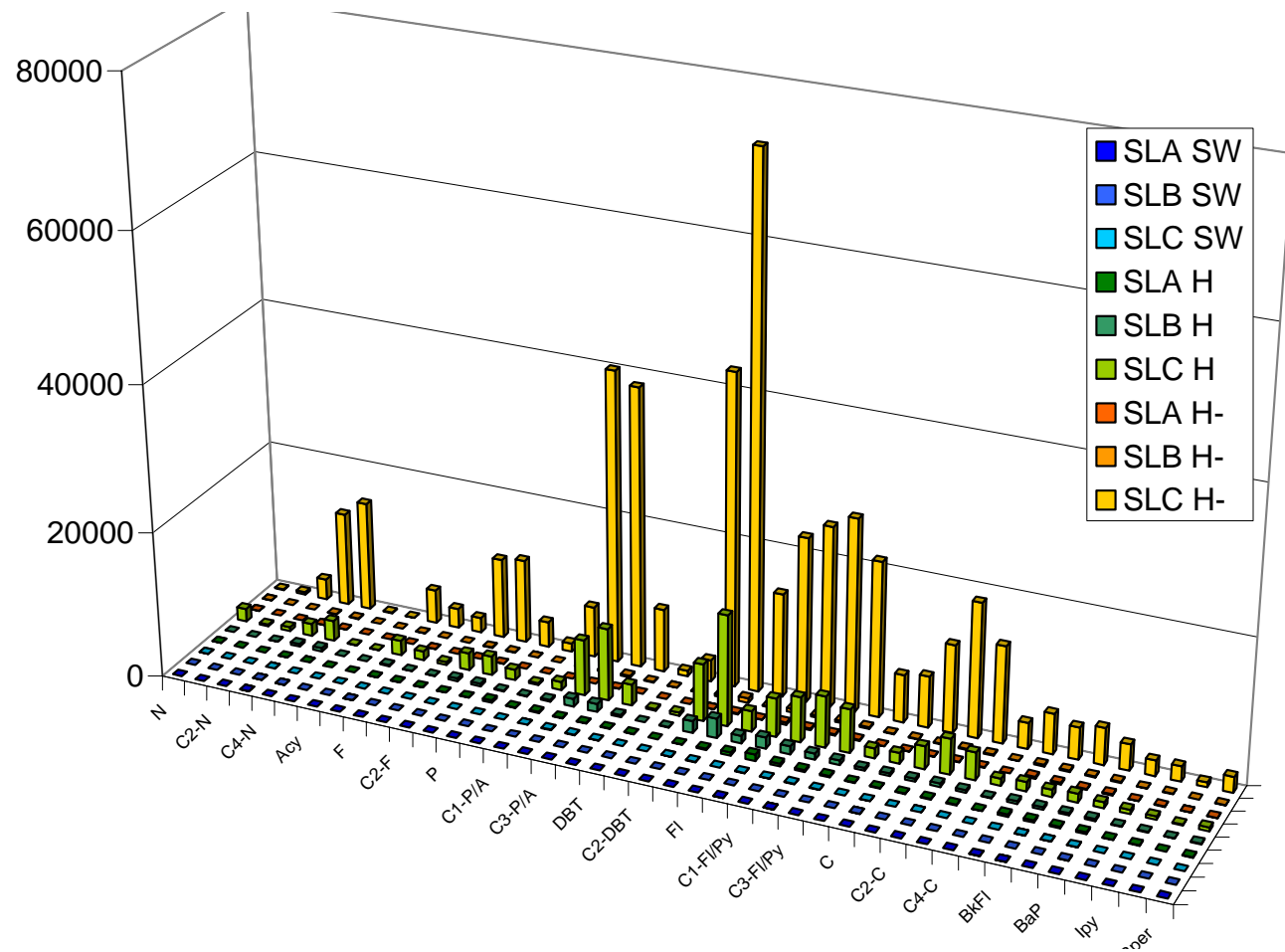


Figure 5-72. SL dissolved PAHs in seawater and H and H- porewater: Porewater PAH levels are comparable to or higher than are seawater levels. Note that while the patterns are similar in all PW samples, concentrations of PW PAHs for both H and H- are significantly higher than are other values. Concentrations in ng/L.

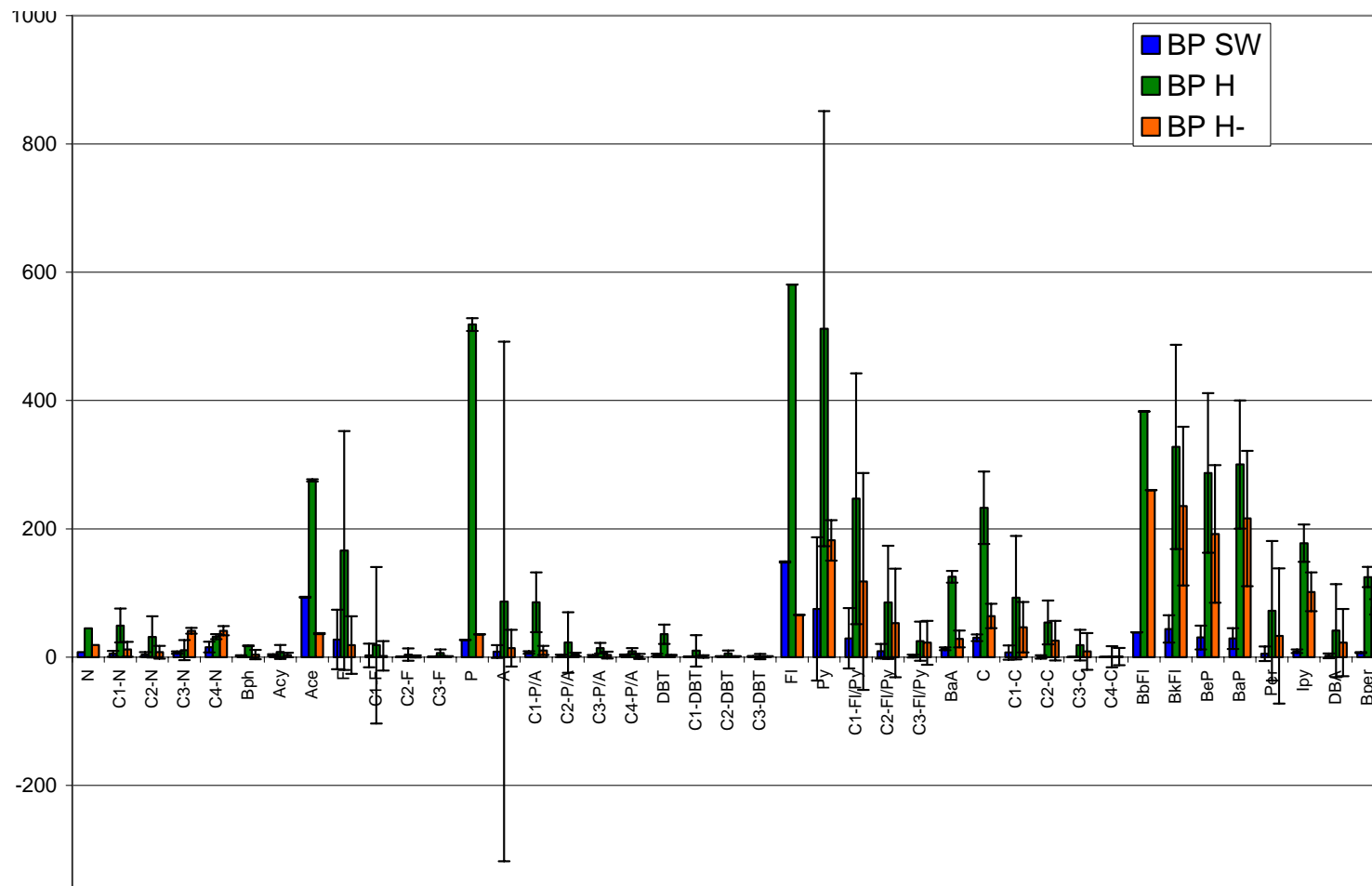


Figure 5-73. BP mean dissolved PAHs in seawater and H and H- porewater.. Concentrations in ng/L, error bars are standard deviations.

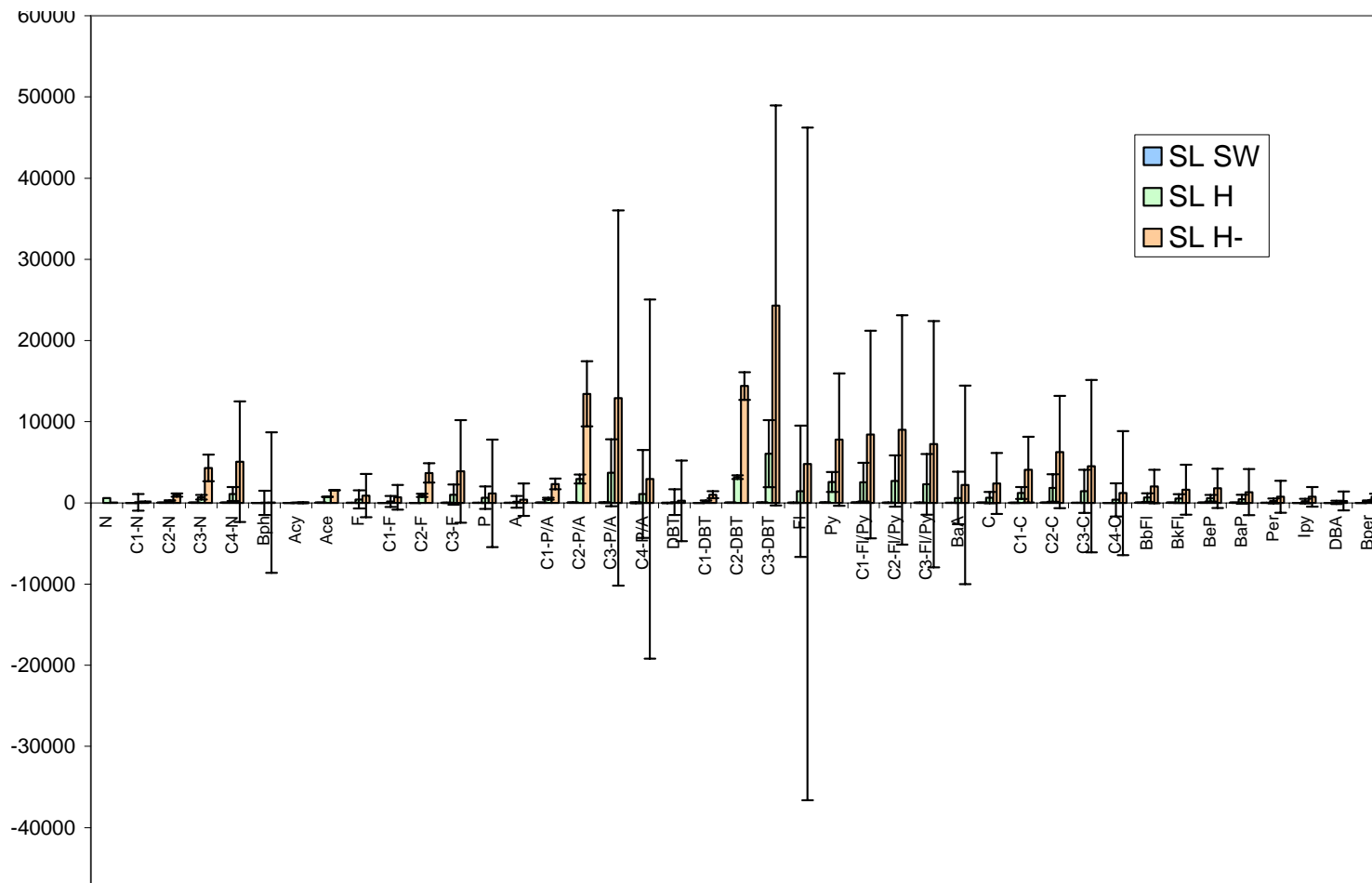


Figure 5-74. SL mean dissolved PAHs in seawater and H and H- porewater. Concentrations in ng/L, error bars are standard deviations.

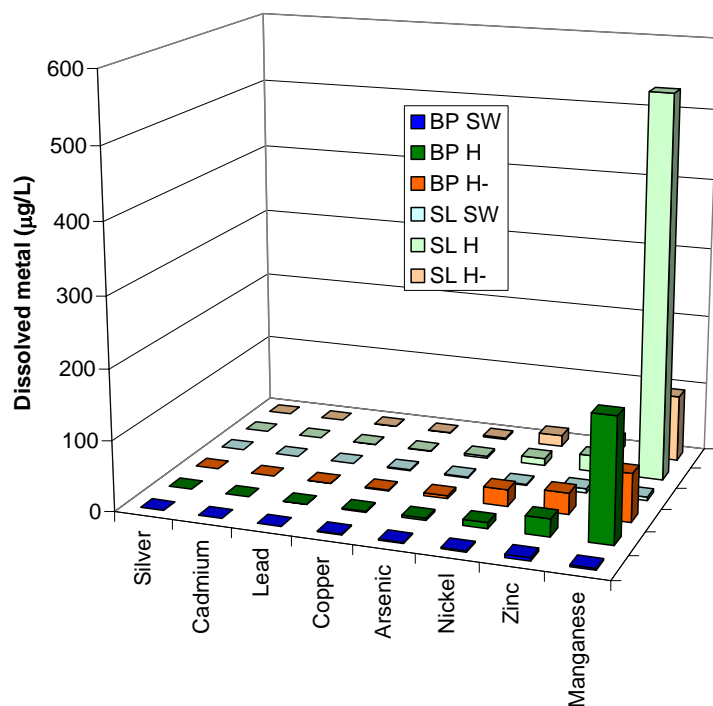


Figure 5-75. Mean dissolved metal concentrations, in µg/L, in BP and SL seawater and porewater composites.

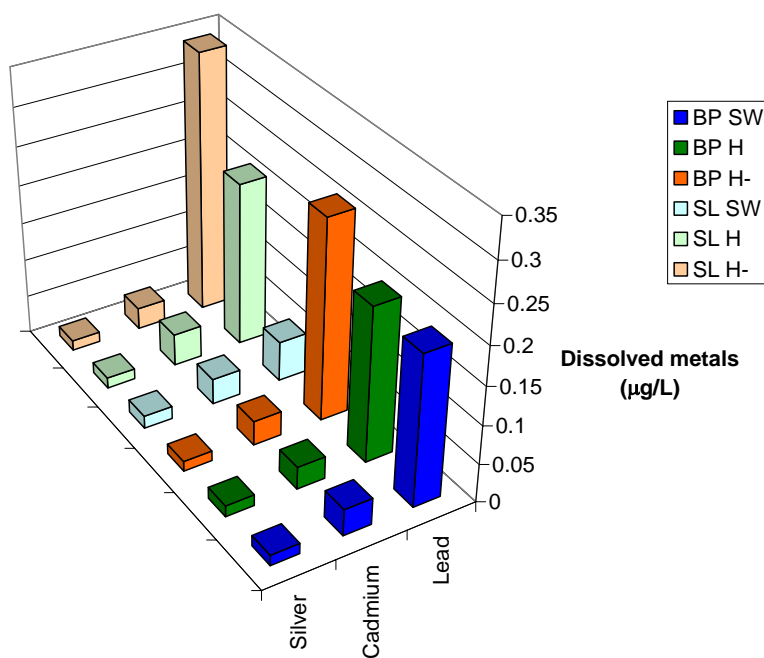


Figure 5-76. Mean dissolved silver, cadmium and lead concentrations, in µg/L, in BP and SL seawater and porewater composites.



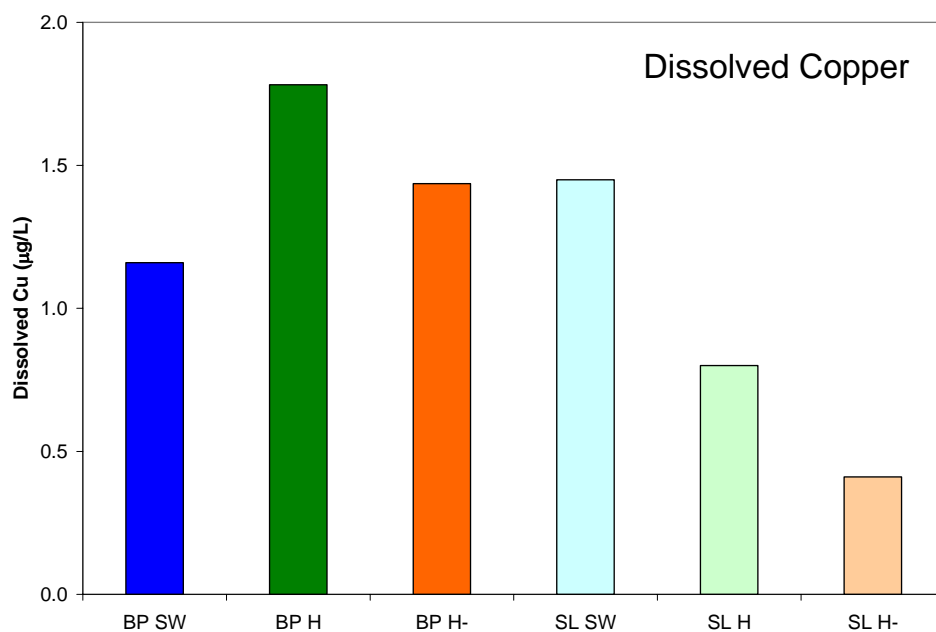


Figure 5-77. Mean dissolved copper concentrations, in µg/L, in BP and SL seawater and porewater composites.

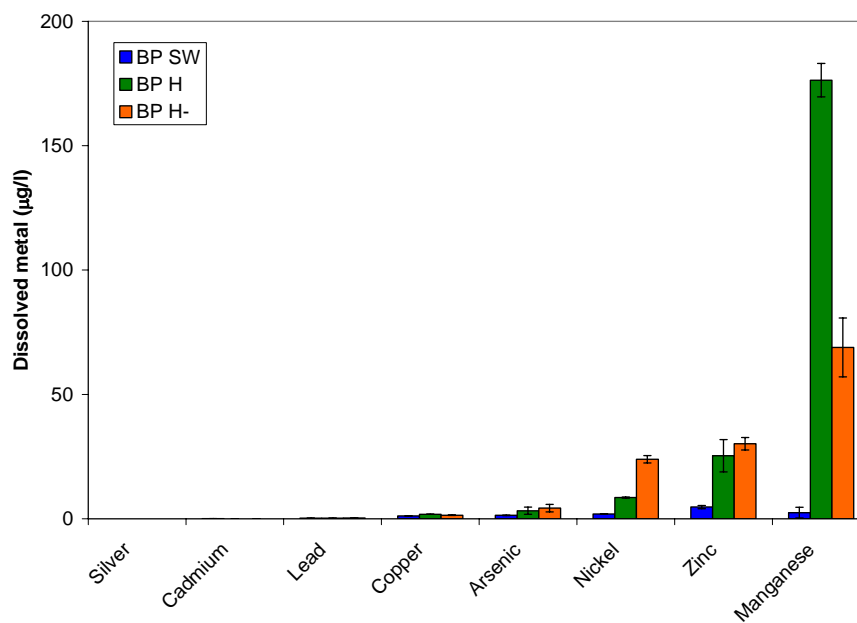


Figure 5-78. Mean dissolved metal concentrations, in µg/L, in BP seawater and porewater composites. Error bars are standard deviations.

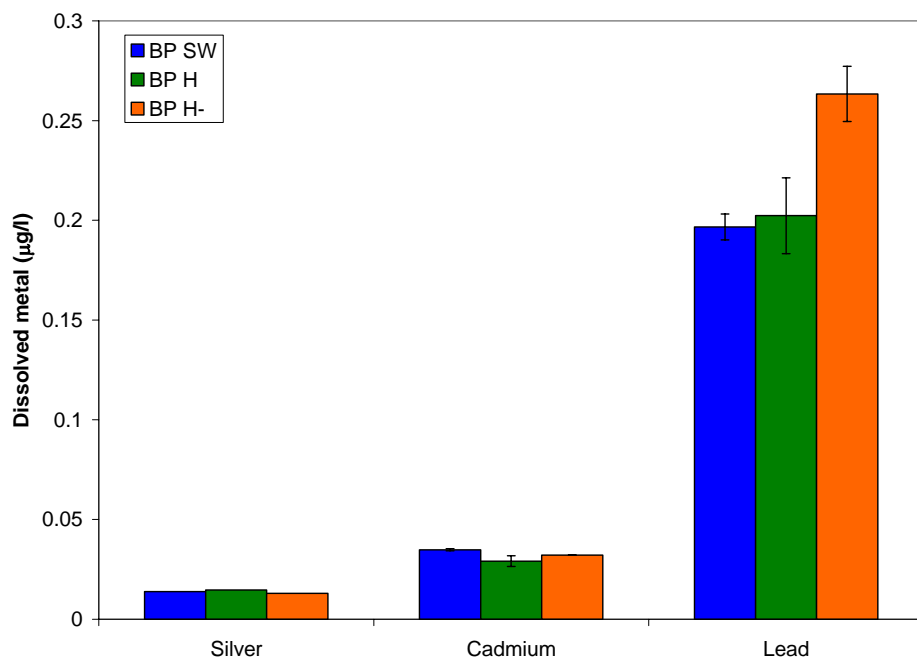


Figure 5-79. Mean dissolved silver, cadmium and lead concentrations, in µg/L, in BP seawater and porewater composites. Error bars are standard deviations.

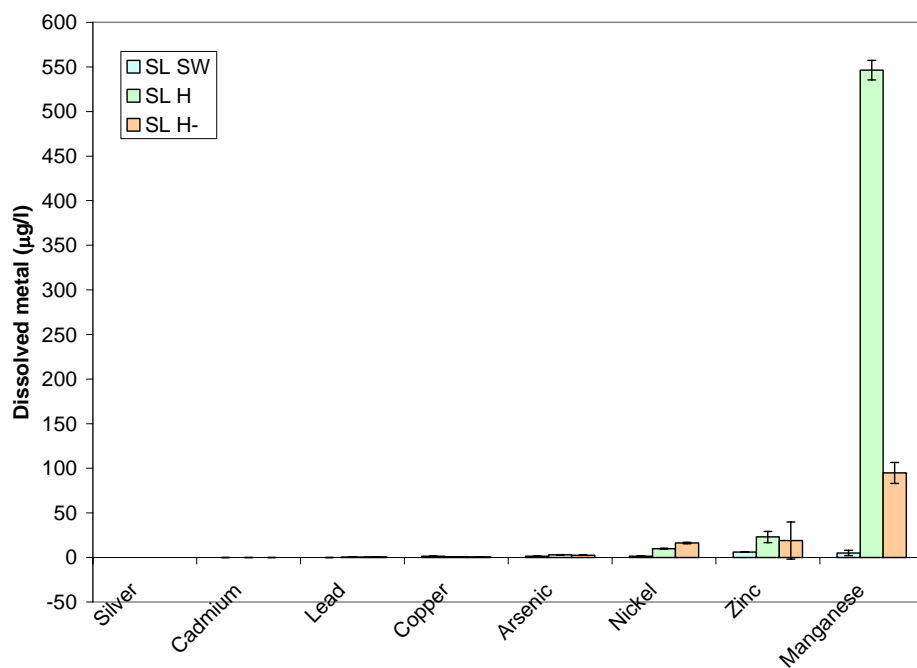


Figure 5-80. Mean dissolved metal concentrations, in µg/L, in SL seawater and porewater composites. Error bars are standard deviations

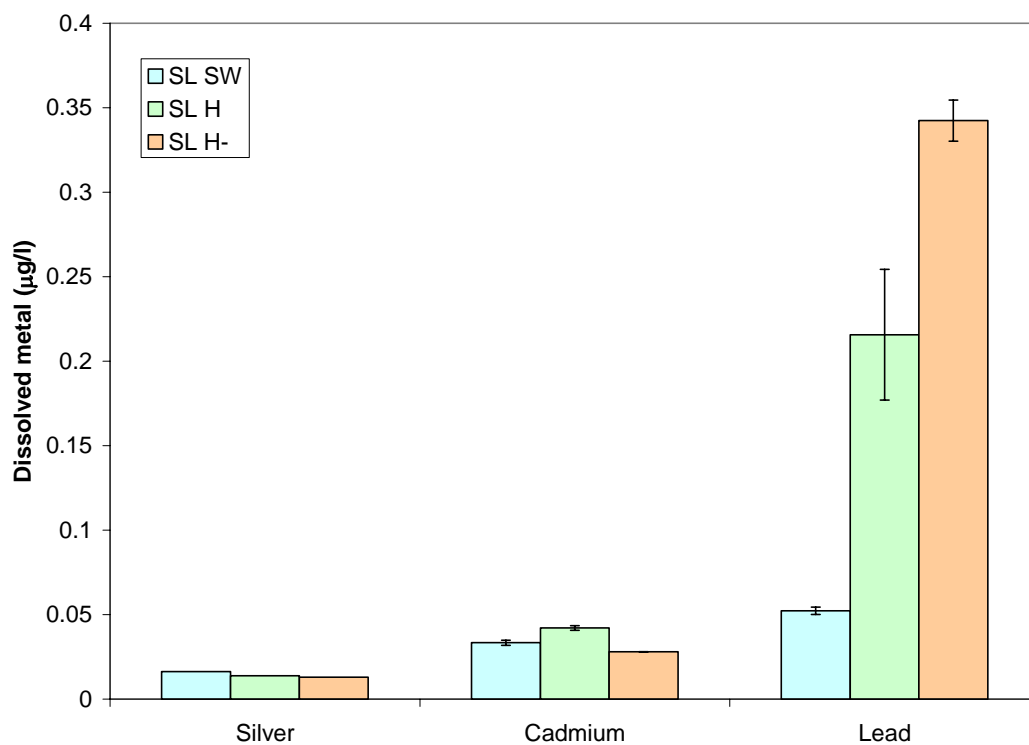


Figure 5-81. Mean dissolved silver, cadmium and lead concentrations, in  $\mu\text{g/L}$ , in SL seawater and porewater composites. Error bars are standard deviations.

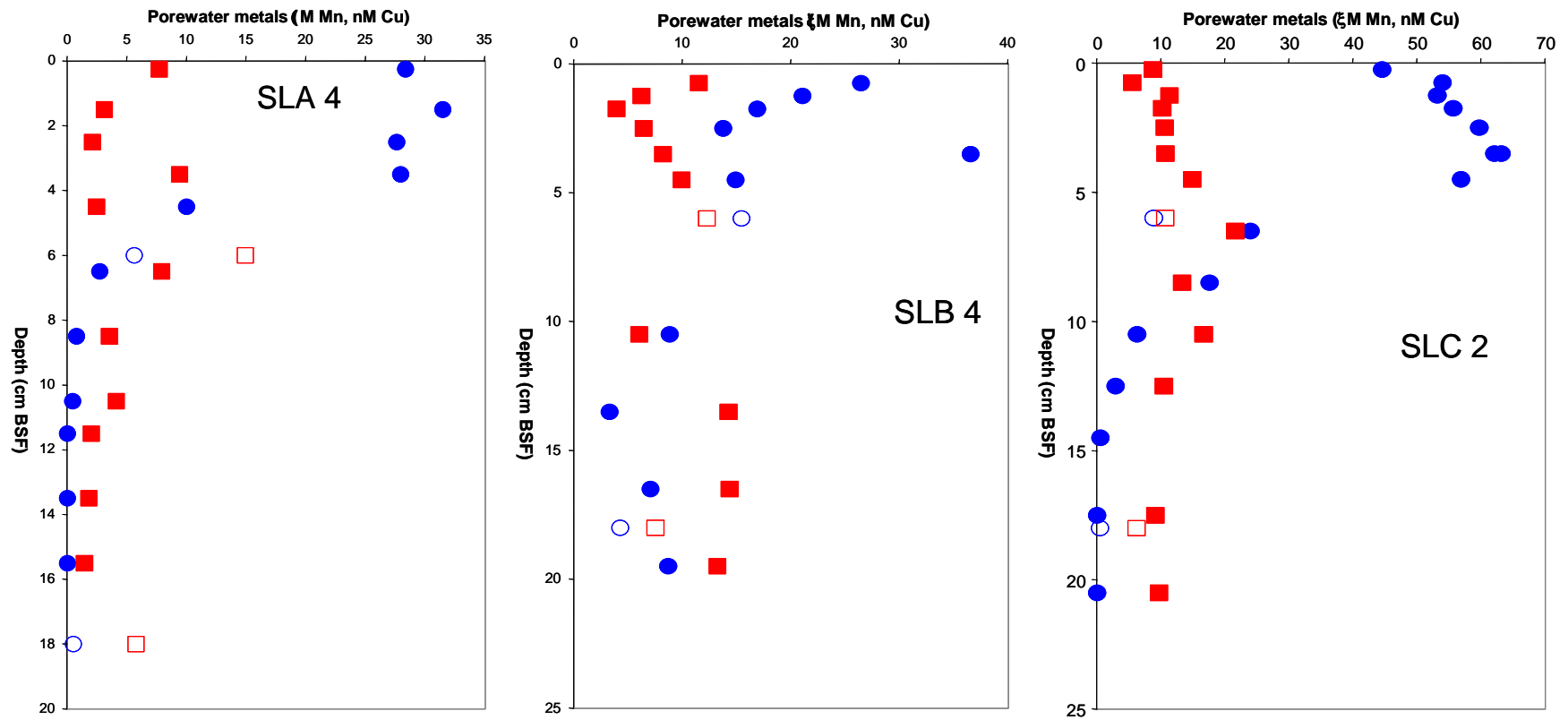


Figure 5-82. Comparison of SL porewater Mn and Cu concentrations in composited core sections (H and H-) vs. high resolution porewater measurements by Gieskes et al. Cu is shown in blue circles (open circles for composites), reported in nM concentrations; Mn is shown in red squares (open squares for composites), reported in  $\mu\text{M}$  concentrations.

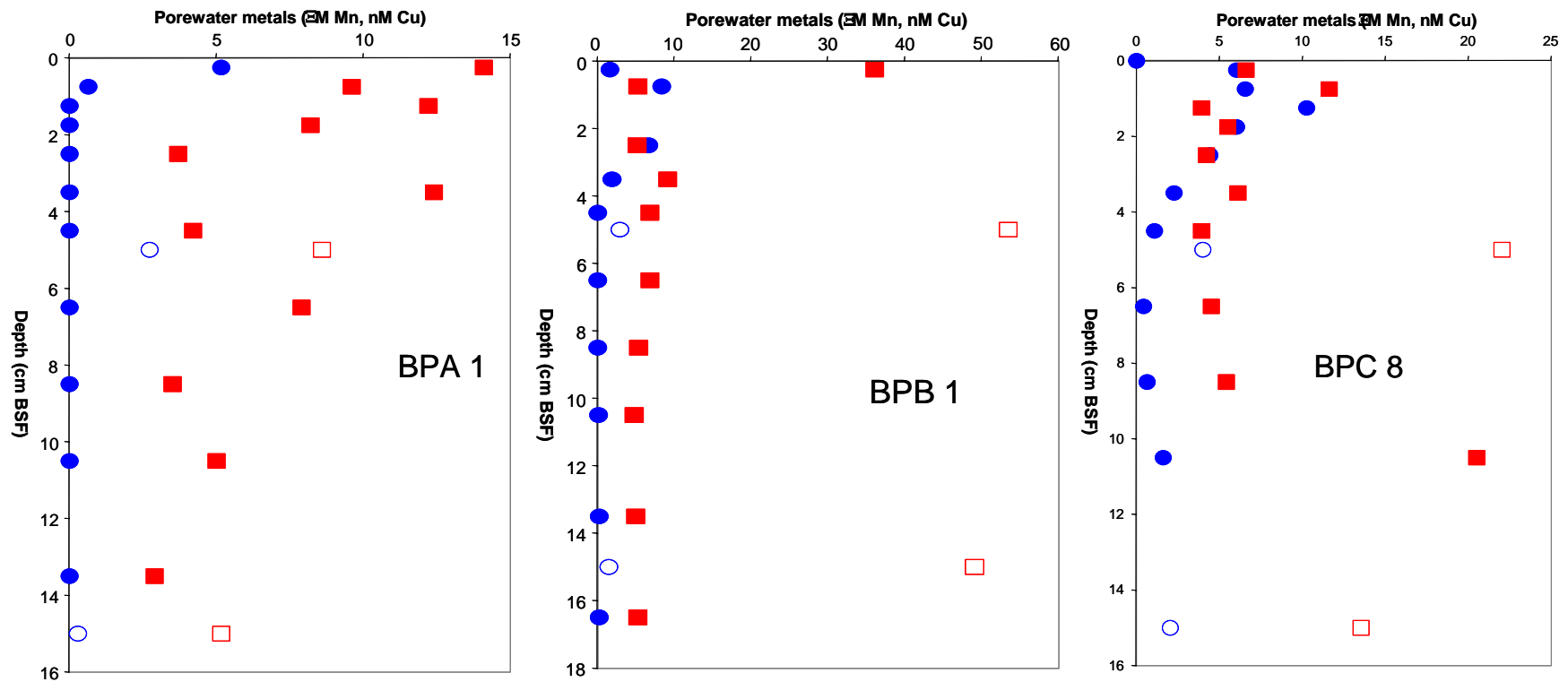


Figure 5-83. Comparison of BP porewater Mn and Cu concentrations in composited core sections (H and H-) vs. high resolution porewater measurements by Gieskes et al. Cu is shown in blue circles (open circles for composites), reported in nM concentrations; Mn is shown in red squares (open squares for composites), reported in  $\mu\text{M}$  concentrations.

Table 5-25. Porewater and seawater chemistry from multicore composites. PAHs are in ng/L; metals are in µg/L.

	BP SW		BP H		BP H-		SL SW		SL H		SL H-	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
Silver	0.01	0	0.01	0	0.01	0	0.02	0	0.01	0	0.01	0
Cadmium	0.03	0.01	0.03	0.02	0.03	0.01	0.03	0	0.04	0.04	0.03	0.01
Lead	0.2	0.07	0.2	0.03	0.26	0.11	0.05	0.02	0.22	0.09	0.34	0.18
Copper	1.16	0.13	1.78	1.46	1.44	1.48	1.45	0.24	0.8	0.14	0.41	0.06
Arsenic	1.39	0.07	3.2	0.23	4.26	1.48	1.43	0.24	3.05	0.57	2.5	0.87
Nickel	1.92	0.65	8.51	6.5	23.9	2.52	1.49	0.16	9.87	6.3	16.3	20.8
Zinc	4.71	2.17	25.3	6.69	30.1	11.8	6.08	3.01	23.0	11.0	19.0	11.7
Manganese	2.41	0.71	176	37.3	68.9	49.0	5.09	3.35	546	275	94.9	120
Naphthalene	7.84	4.47	44.8	26.3	19.2	11.4	3.46	0.69	602	1028	42.0	56.5
Acenaphthylene	3.24	0.63	8.14	1.72	3.43	0.62	1.04	0.45	9.24	11.0	19.3	30.2
Acenaphthene	93.4	46.2	275	186	36.7	44.7	5.74	4.87	751	1124	1553	2659
Fluorene	27.5	18.4	166	121	18.9	22.8	1.13	0.64	431	684	889	1530
Phenanthrene	26.8	10.1	519	404	35.5	28.6	4.11	3.63	634	722	1167	2001
Anthracene	8.61	1.78	86.8	46.7	13.9	7.08	1.54	0.97	128	120	387	664
Fluoranthene	148	112	581	339	65.89	31.6	15.3	10.5	1439	1241	4796	8156
Pyrene	75.2	47.1	512	195	182	169	36.6	12.3	2572	2375	7795	12795
Benzo(a)anthracene	13.0	5.33	125	56.5	28.3	19.0	3.79	0.13	600	687	2211	3750
Chrysene	30.3	11.2	233	96.2	64.2	39.3	15.4	7.47	644	738	2390	4045
Benzo(b)fluoranthene	38.7	21.4	383	159	260	124	17.7	1.75	656	533	2026	3070
Benzo(j/k)fluoranthene	43.9	18.6	328	124	235	107	18.1	2.97	536	390	1612	2423
Benzo(e)pyrene	30.6	16.2	287	99.9	192	105	11.3	2.05	568	553	1791	2848
Benzo(a)pyrene	29.1	11.3	300	109	216	105	14.9	2.63	459	309	1316	1965
Perylene	5.32	2.62	72.3	29.2	33.0	30.2	3.17	0.63	238	283	745	1215
Indeno(1,2,3-c,d)pyrene	9.26	3.75	178	72.5	102	52.4	3.49	0.84	217	212	744	1171
Dibenz(a,h)anthracene	2.05	0.77	41.4	16.0	22.6	11.9	1.08	0.35	65.6	68.8	232	369
Benzo(g,h,i)perylene	7.06	2.99	125	44.2	78.2	36.2	2.78	0.39	226	247	763	1218

## 5.5 DEPTH PROFILES OF BACTERIAL METABOLISM AND PAH BIODEGRADATION

### Introduction

Heterotrophic bacteria require a source of oxygen to rapidly metabolize complex and recalcitrant carbon sources like lignin, TNT (TriNitroToluene) and polyaromatic hydrocarbons (PAHs). Bacterial assemblages can rapidly deplete oxygen in marine sediments that depend primarily on diffusive processes for aeration. However, as we reported in a previous study on San Diego Harbor sediments (Montgomery et al. 2003), the activities of burrowing macrofauna can stimulate bacterial metabolism of PAHs and heterotrophic production, in general. In this follow up study, we also measured heterotrophic bacterial production, PAH mineralization, and lignin subunit concentration with depth in cores taken from bioturbated and less bioturbated stations in Pearl Harbor, HI.

### Material and Methods

#### Sampling

Replicate gravity cores housed on a multicorer were sampled from three stations in each Southeast Loch and Bishop's Point in Pearl Harbor, HI. Stations in Southeast Loch (SL) were sampled on 17 December 2002 and Bishop's Point (BP) sampled on 18 December 2002. The multicorer was deployed off a small research vessel and transferred to the laboratory at ambient temperature within 3 hours. Two cores from Southeast Loch stations (SLA2, SLC3) and Bishop's Point stations (BPB2, BPC6) were sectioned and assayed for bacterial production and PAH mineralization while a third replicate core from each site (SLA1, SLC6, BPB3, BPC3) was sectioned for PAH and lignin subunit concentration. Slurries for biological assays were made from filtered water overlying the respective cores.

#### PAH Mineralization

PAH mineralization assays were initiated within three hours of sediment sample collection using a modification of Boyd et al. (1996) and Pohlman et al. (2002). Radiotracers three sentinel PAHs: UL- $^{14}\text{C}$ -naphthalene ( $18.6 \text{ mCi mmol}^{-1}$ ), 3- $^{14}\text{C}$ -fluoranthene ( $45 \text{ mCi mmol}^{-1}$ ), and 9- $^{14}\text{C}$ -phenanthrene ( $47 \text{ mCi mmol}^{-1}$ ) were purchased from Sigma Chemical. They were added in separate incubations to surface sediment samples (1 mL wet volume) in 100×16 mm test tubes to a final concentration of about  $0.2 \mu\text{g g}^{-1}$  (depending on specific activity). Isotope dilution was calculated from the ambient test PAH concentration. Samples were incubated no longer than 24 h at *in situ* temperature and evolved  $^{14}\text{CO}_2$  was captured on NaOH-soaked filter papers.  $\text{H}_2\text{SO}_4$  was added to end incubations and to partition any remaining  $\text{CO}_2$  into headspace of the tube and to the filter paper trap. The filter paper traps containing metabolized  $^{14}\text{CO}_2$  were removed, radioassayed and subsequently used to calculate substrate mineralization.

### Heterotrophic Bacterial Production

The leucine incorporation method (Kirchman et al. 1985, Kirchman 1993, Smith and Azam 1992) was used to measure bacterial production as adapted by Montgomery et al. (1999). A 0.50  $\mu\text{L}$  of wet surface sediment subsample from each station was added to 2 mL centrifuge tubes (three experimental and one control) which were pre-charged with [ $^3\text{H}$ -4,5]-L-leucine ( $154 \text{ mCi mmol}^{-1}$ ). The sediment was extracted from the benthic grab sample and added to the 2 mL tube using a 1 mL plastic syringe with the end cut off. One mL of 0.22  $\mu\text{m}$  (nom. pore dia.) filtered bottom water (collected <1 m above bottom) was then added to each tube to form a sediment slurry. Samples were incubated for 1-2 hours at *in situ* temperatures and subsequently processed by the method of Smith and Azam (39). A constant isotope dilution factor of 1000 was used for all samples. This was estimated from actual measurements of sediment dissolved free amino acids (40) and saturation experiment estimates (41). One mL syringed samples of wet sediment were dried at 50  $^{\circ}\text{C}$  and used to convert production values to dry weight. Leucine incorporation rate was converted to bacterial carbon using factors determined by Simon and Azam (1989).

### PAH Concentration

Ambient PAH concentrations of the 18 semi volatile priority pollutants were determined by drying 10-15 g sediment samples with diatomaceous earth, accelerated solvent extraction of dried samples and GC/MS analysis of the extracts (Fisher et al. 1997). *p*-Terphenyl- $\text{d}_{14}$  and 2-fluorobiphenyl were used as surrogate standards and the method is further described in Pohlman et al. (2002).

### Radiotracer Mineralization

Radiotracer mineralization assays were initiated within three hours of sediment sample collection using a modification of Boyd et al. (1996) and Pohlman et al. (2002). As radiotracers, we used three sentinel PAHs: UL- $^{14}\text{C}$ -naphthalene ( $18.6 \text{ mCi mmol}^{-1}$ ), 3- $^{14}\text{C}$ -fluoranthene ( $45 \text{ mCi mmol}^{-1}$ ), and 9- $^{14}\text{C}$ -phenanthrene ( $47 \text{ mCi mmol}^{-1}$ ) that were purchased from Sigma Chemical. 2,4,6- $^{14}\text{C}$ -TNT ( $50 \text{ mCi mmol}^{-1}$ ) and U- $^{14}\text{C}$ -catechol ( $3.5 \text{ mCi mmol}^{-1}$ ) were purchased from American Radiochemical Chemicals Inc. They were added in separate incubations to surface sediment samples (1 mL wet volume) in 100 $\times$ 16 mm test tubes to a final concentration of about 0.2  $\mu\text{g g}^{-1}$  (depending on specific activity). Isotope dilution was calculated from the ambient test PAH concentration and additions were intended to be < 10% of ambient PAH concentration to minimize selective pressure on the natural bacterial assemblage. Catechol and TNT mineralization were measured on all core slices as part of a related task on the effect of bioturbation on carbon metabolism, but will be reported here. Ambient catechol and TNT concentrations were expected to be below detection and were not measured, thus these compounds are not treated as tracers of ambient pool mineralization but rather potential for assemblage utilization. Samples were incubated no longer than 24 h at *in situ* temperature and evolved  $^{14}\text{CO}_2$  was captured on NaOH-soaked filter papers.  $\text{H}_2\text{SO}_4$  was added to end incubations and to partition any remaining  $\text{CO}_2$  into headspace of the tube and to the



filter paper trap. The filter paper traps containing metabolized <sup>14</sup>CO<sub>2</sub> were removed, radioassayed and subsequently used to calculate substrate mineralization.

### Lignin Concentration

Lignin concentration in sediment samples was measured using an alkaline hydrolysis oxidation method to liberate lignin-derived methoxyphenols (LPs) derived from the parent lignin compound (Table 1) as previously described by Montgomery and Osburn (2003). The LPs were subsequently derivatized with 1% BSTFA to silylate exchangeable hydrogen and then analyzed by GC/MS (Goni and Montgomery 2000). We used a J&W Scientific DB-1 column (60 m X 0.32 mm i.d., 0.2 µm film thickness) with the following analytical program: 100 °C initial temperature, 4 °C/min temperature ramp, 320 °C final temperature, and final hold of 10 minutes). A splitless, on-column injector with a flow rate of 1.3 mL/min mode was used for the GC. MS spectra of eluted peaks were interpreted using an internal laboratory library we created based on the retention times and m/z values for known standard LPs we purchased from Sigma-Aldrich. Acid, aldehyde, and ketone moieties of phenols liberated from the lignin hydrolysis and oxidation provide useful geochemical information about terrigenous organic carbon derived from vascular plants in coastal sediments (Hedges and Ertel, 1982). These moieties can be used to describe the collective geochemical history of the organic carbon (tissue source, diagenetic history) *in situ* and provide a context (in addition to contaminant concentration and speciation) in which to interpret microbial activity in sediments (Table 1).

Table 5-26. Summary of lignin-derived phenol measurements and parameters that describe composition and reactivity of terrigenous organic carbon in sediments.

Parameter	Definition	Significance
V	Vanillyl family	Synthesized in all vascular plants
S	Syringyl family	Synthesized only in angiosperms
C	Cinnamyl family	Synthesized only in nonwoody tissues (leaves, needles)
S/V	Ratio of syringyl to vanillyl phenols	Values > 0 if large contribution of angiosperms
C/V	Ratio of cinnamyl to vanillyl phenols	Values = 0 if gymnosperm wood; >0 if gymnosperm needles
Λ	mg phenol per 100 mg of organic carbon (OC)	Lignin normalized to organic carbon content of sediments
[ad/al] <sub>v</sub>	Ratio of acid to aldehyde moieties in vanillyl family	Values > 0.5 indicate oxidative degradation (microbial); (Opsahl and Benner, 1995)

## Results

Heterotrophic bacterial production was measured at two stations at Bishop's Point, BPB and BPC, and at two stations at Southeast Loch, SLA and SLC. Production remained above  $3.3 \mu\text{g C kg}^{-1} \text{ d}^{-1}$  in core slices representing the top 9 cm of both Southeast Loch stations (Figure 5-84) and was as high as  $30.9 \mu\text{g C kg}^{-1} \text{ d}^{-1}$  in the top 2 cm at station SLA. Bacterial metabolism was much lower at the Bishop's Point stations being only slightly above  $5 \mu\text{g C kg}^{-1} \text{ d}^{-1}$  (BPB, 5.8; BPC, 5.9) in the top 2 cm with the 2-4 cm slightly lower (2.7, Figure 5-85). Values for the stations at each site were similar to each other in pattern of decrease with depth and in absolute value for each core section and Southeast Loch production was higher than that at Bishop's Point.

Total PAH concentration was below 2 ppm for all core sections at both Southeast Loch stations (Figure 5-86) and changes were generally unremarkable with depth though the deepest section was also the lowest in PAH concentration (SLA, 0.88; SLC, 0.74). At Bishop's Point, PAH concentration was much higher than at Southeast Loch, in all core section at station BPC and higher in the top 0-4 cm at BPB (10.13 ppm; Figure 5-87). At BPB PAH concentration generally decreased with depth whereas BPC had the second highest concentration (6.23 ppm) in the deepest core section (9-13 cm).

Radiotracer mineralization rates of three sentinel PAHs were measured to determine how rapidly the ambient pool of PAH was being metabolized by the heterotrophic bacterial assemblage. At Bishop's Point station BPB, naphthalene and fluoranthene mineralization rates were relatively low throughout all core sections but highest in the top 0-2 cm (Figure 5-88), as expected for this oxygen utilizing process. Phenanthrene mineralization rates were generally highest of the three PAHs measured and were elevated in the upper 0-4 cm of the BPB cores. At Bishop's Point station BPC, PAH mineralization was low in the top 0-2 cm and the bottom 9-13 cm (Figure 5-89) which were also the depths of highest ambient PAH concentration for all cores (Figure 5-87 versus Figure 5-86). Phenanthrene and fluoranthene mineralization was highest from core sections representing 2-9 cm below the bottom water-sediment interface. PAH mineralization rates at both Southeast Loch stations was generally higher than at corresponding depths for Bishop's Point cores and generally highest in the top 0-6 cm (Figure 5-90, Figure 5-91) Phenanthrene mineralization was often higher in each core section than that for naphthalene and fluoranthene (Figure 5-90, Figure 5-91). Catechol mineralization was generally highest in core slices representing 2-9 cm deep and was similar among all four stations (Figure 5-92). This pattern contrasts with that for total heterotrophic production (Figure 5-84, Figure 5-85) suggesting that catechol mineralization rates may be associated with aromatic metabolism rather than a simple function of carbon metabolism, in general. TNT mineralization rates were generally higher in Southeast Loch core sections from both stations than corresponding section from Bishop's Point stations but did not show distinct differences with depth from any of the four stations (Figure 5-93).

Lignin phenol distributions in the sediment cores collected at Southeast Loch and at Bishop's Point were used to assess the refractory natural organic material buried in sediments. The S/V versus C/V ratios suggested that the source of terrigenous organic matter and the type of vascular tissue was different at each site. Southeast Loch has more influence from angiosperm tissue than does Bishop's Point, especially relative to station BPB (Figure 5-94). At Bishop's Point, there was low abundance of syringyl phenols and no cinnamyl phenols; further, organic carbon-normalized lignin concentrations ( $\Lambda$ ) were about one third those from Bishop's Point (Figure 5-95). In terms of diagenetic state, or reactivity, both sites are remarkably similar in the top 0-6 cm with [ad/al]<sub>v</sub> ratios 0.7 or above indicating that the lignin was relatively degraded (Figure 5-96). Below 6 cm, core sections from station BPC appeared less degraded with depth than the three other stations. Finally, concentration of cinnamyl phenols relative to organic carbon was higher in Southeast Loch than at Bishop's Point. Station SLC had even higher total cinnamyl concentration than SLA (Figure 5-97) and the total cinnamyl concentration, as well as, the cinnamyl to vanillyl ratio (C/V) both showed some correlation with fluoranthene turnover at Southeast Loch (Figure 5-98).

## Discussion

This study compared the depth related changes bacterial metabolism of organic matter in the sediments of two sites in Pearl Harbor, Bishop's Point and Southeast Loch. The two stations sites were chosen to be different from each other based on their degree, types and depth of bioturbation with Southeast Loch being the more bioturbated of the two sites (as determined using REMOTS camera analyses). Two coring stations at each site were selected to address the site variability at each station. Our previous two studies at Bishop's Point, found large changes in PAH concentration and rapid PAH turnover in the surface sediments (Montgomery et al. 2002). These changes in ambient PAH concentration may be due to creosote treatment of docks or the presence of a refueling dock. The PAH turnover and mineralization rate by bacteria was among the most rapid that our group has reported for any estuarine site and may be due to adaptation of the bacterial assemblage to episodic inputs of petroleum products (Montgomery et al. 2002). In this study, we found that PAH concentrations in the surface sediments were much lower than during our previous samplings in 1998 and 1999 but higher than found in our related study of Paleta Creek in San Diego Bay (Montgomery et al. 2003).

Rates of total bacterial metabolism (heterotrophic production) decreased rapidly with depth but were much higher at Southeast Loch than at Bishop's Point. Similarly, PAH mineralization rates were higher at Southeast Loch than at Bishop's Point and extended down to the likely depths of bioturbation at each site: upper 4-6 cm at Bishop's Point and upper 9 cm at Southeast Loch. These findings are consistent with the hypothesis furthered in our previous study in San Diego Bay, that the burrowing and irrigational activities of macrofauna can stimulate bacterial degradation of PAHs with depth in sediments that would otherwise be anoxic (Montgomery et al. 2003). One odd finding was that both production and PAH mineralization was very low in the top 0-2 cm of Bishop's Point station, BPC but then mineralization was much higher from 2-6 cm. One hypothesis is that the surface sediments (0-2 cm) were relatively armored but that tube forming macrofauna were contributing to introduction of oxygen farther down into the sediments but not at the surface itself.

Catechol is a relatively labile compound but it may represent an intermediate in the metabolism of many aromatics such as PAHs, lignin, and more exotic aromatics like TNT. That is, bacterial assemblages that can rapidly degrade more recalcitrant aromatics, might mineralize catechol more rapidly than assemblages that are predominantly metabolizing non-aromatic carbon sources. For both sites, rates of catechol activity did not directly correspond to rates of production (highest in the top section), as they would if catechol mineralization rate was a general function of total metabolic activity. Rather, the rates were higher in the upper 9 cm of both stations corresponding to depths of enhanced PAH metabolism and the presence of more-degraded lignin. Thus, rapid catechol mineralization may be more indicative of a bacterial assemblage that is metabolizing aromatic carbon sources to support production. In addition, TNT metabolism was much higher in the more bioturbated sites but did not show a distinct pattern with depth. In terrestrial systems, both aerobic and anaerobic metabolic processes are used for complete mineralization of TNT and this may also be a requirement for marine systems. The need of the bacterial assemblage for alternating aerobic and anaerobic microenvironments may have led to our observed depth profile differences between Southeast Loch and Bishop's Point.

A second component of this study involved assessing the biogeochemistry of lignin and relating this to bacterial metabolism of aromatic organic matter in the sediments. Comparing the total concentration and ratio of phenolic moieties of lignin in the sediments of Southeast Loch and Bishop's Point suggests there are different sources of organic matter to the two sites. Pearl Harbor is heavily urbanized and probably much of the angiosperm signal at the Southeast Loch may be due to upland drainage in the sub-watershed, whereas Bishop's Point is near the mouth of the Harbor and likely has marine dilution of the lignin signal in the sediments. In general, based on the  $[ad/al]_v$  and the C/V ratios, the lignin appeared more degraded in the top 9 cm at all stations and at Southeast Loch relative to Bishop's Point. These results are consistent with preferential removal of vanillyl phenols during the degradation of lignin (Goni et al., 1993; Hedges et al., 1988). Some relationship was found between the C/V ratio and the turnover time of fluoranthene which suggests that there may be some relationship between degradation of some PAHs and source tissue of lignin. One should caution that the fluoranthene turnover measurements and the biogeochemical processes that generated the lignin phenol ratios occur dramatically different time scales. Catechol mineralization was highest from 2-9 cm below the bottom water suggesting that aromatic compounds may be playing a larger role in supporting bacterial production in the bioturbation zone below the upper few cm than at other depths.

We found that PAH mineralization was elevated in the bioturbated zones from both stations relative to core subsections from below the bioturbated zone. In addition, ambient PAH concentrations were higher at the less bioturbated site. This is consistent with the hypothesis that the activities of benthic infauna stimulate bacterial metabolism of PAHs.

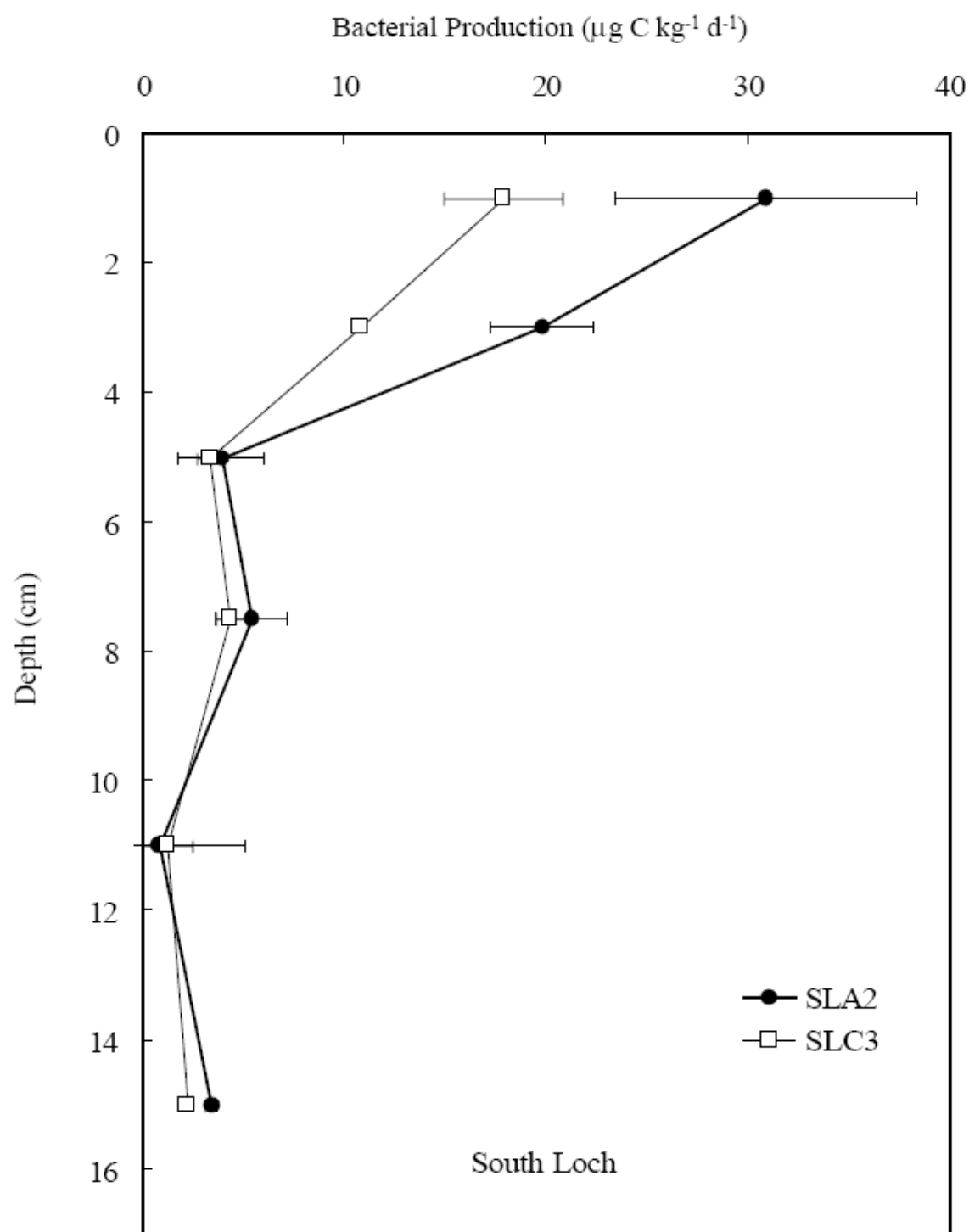


Figure 5-84. Bacterial production ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) versus depth (cm) in core slices taken at two stations (SLA2 and SLC3) in Southeast Loch, Pearl Harbor, HI.

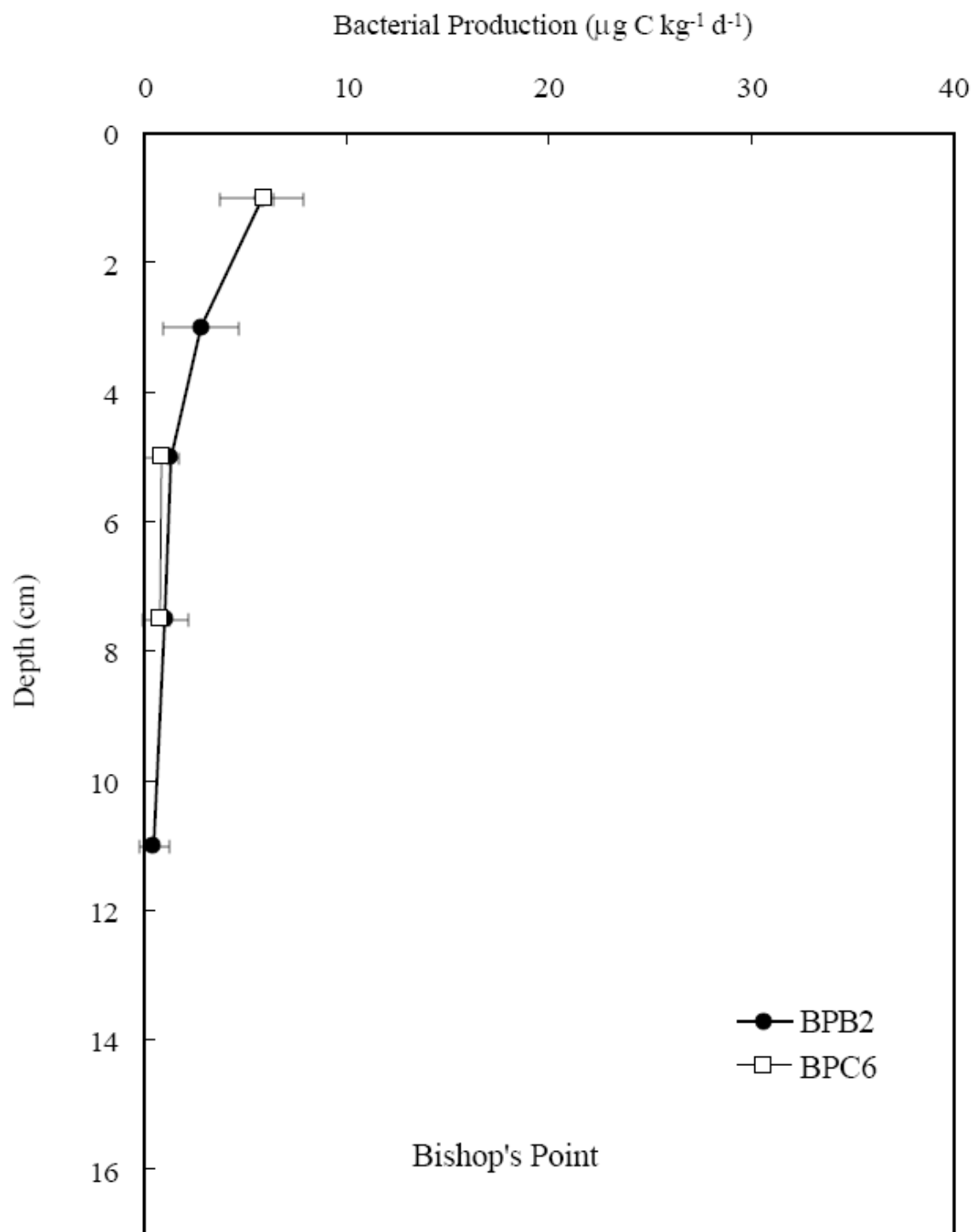


Figure 5-85. Bacterial production ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) versus depth (cm) in core slices taken at two stations (BPB2 and BPC6) in Bishop's Point, Pearl Harbor, HI.

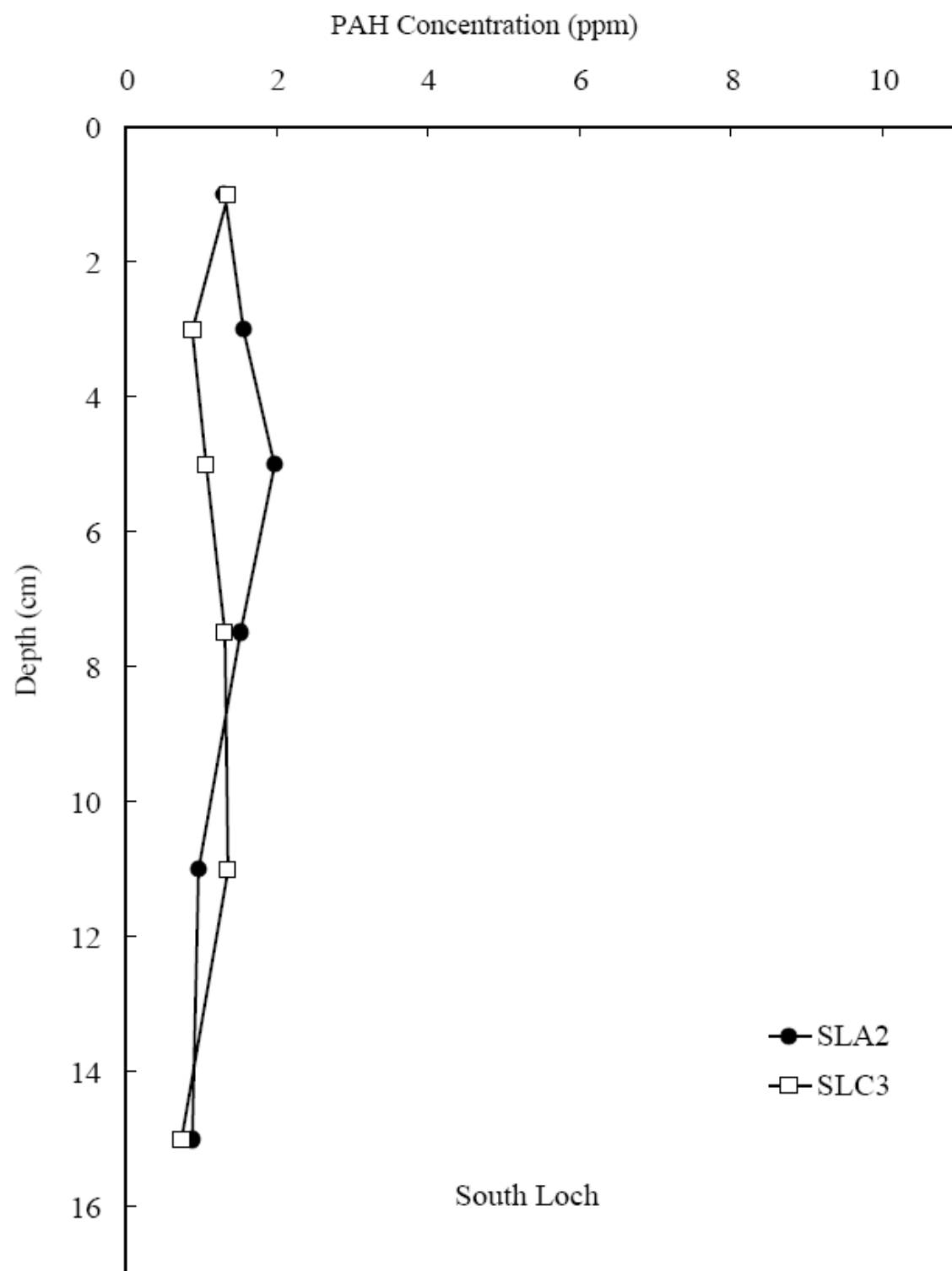


Figure 5-86. PAH concentration (ppm) versus depth (cm) in core slices taken at two stations (SLA2 and SLC3) in Southeast Loch, Pearl Harbor, HI.

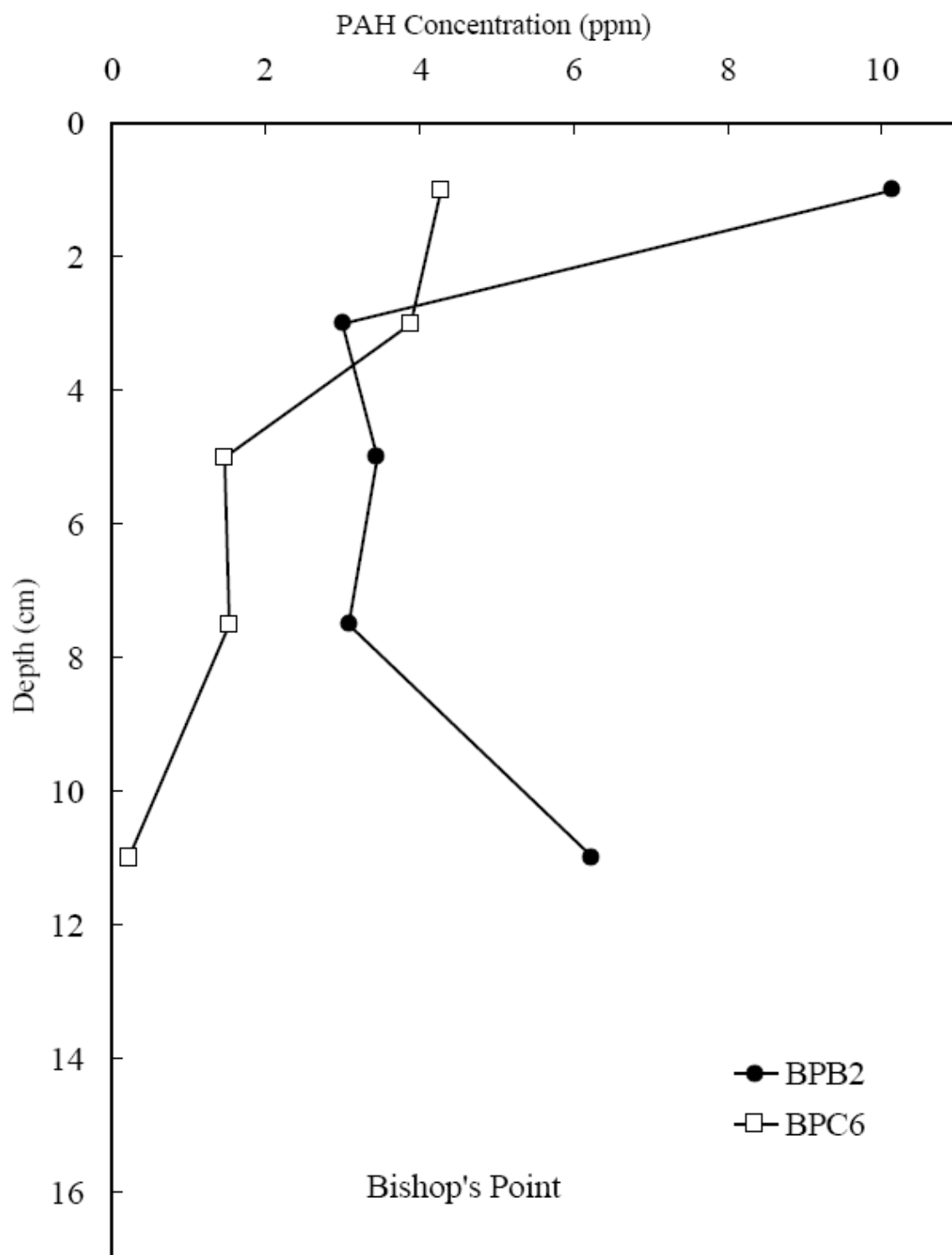


Figure 5-87. PAH concentration (ppm) versus depth (cm) in core slices taken at two stations (BPB2 and BPC6) in Bishop's Point, Pearl Harbor, HI.



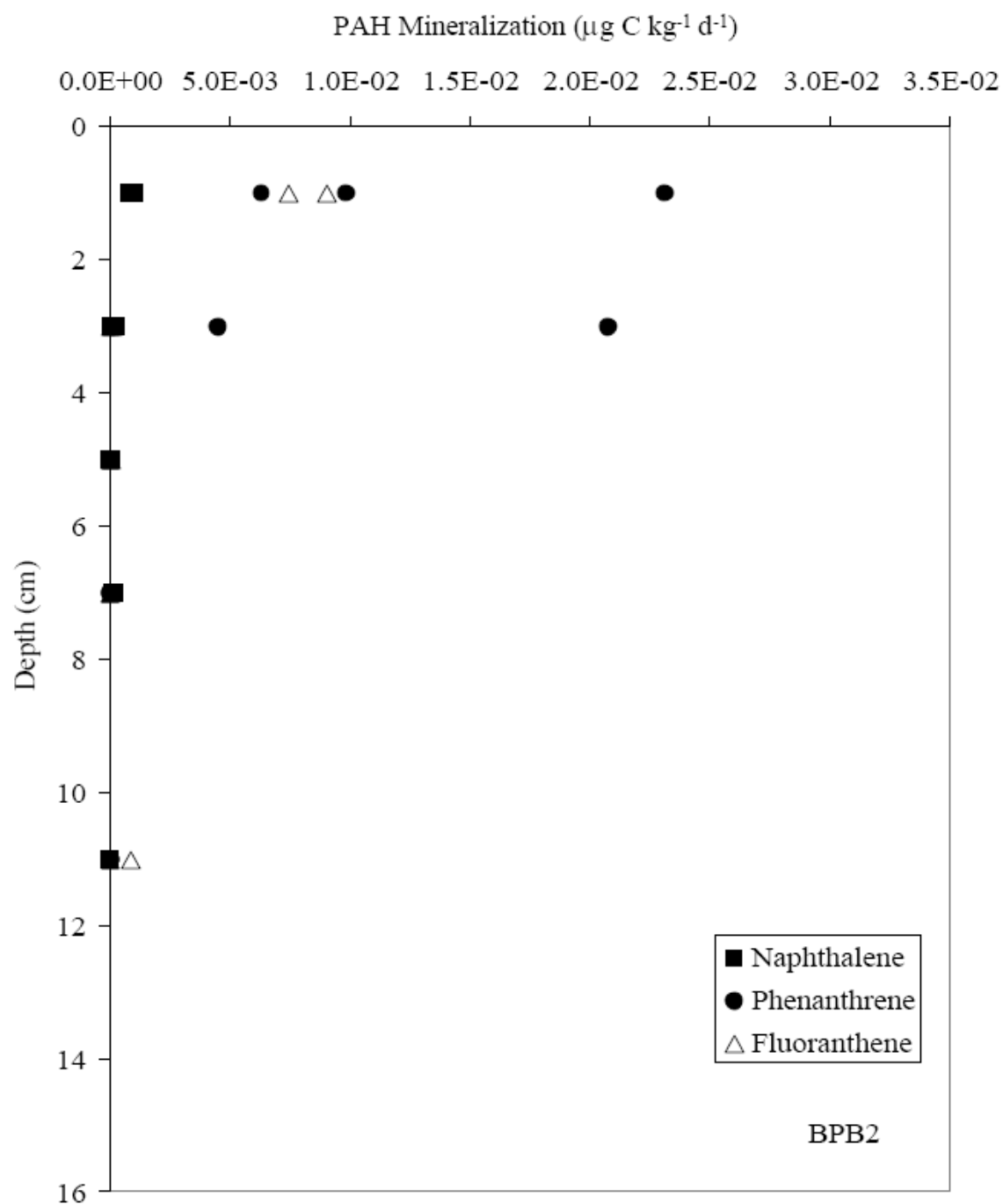


Figure 5-88. Mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) of the PAHs, naphthalene, phenanthrene and fluoranthene versus depth (cm) in core slices taken at station BPB2 in Bishop's Point, Pearl Harbor, HI.

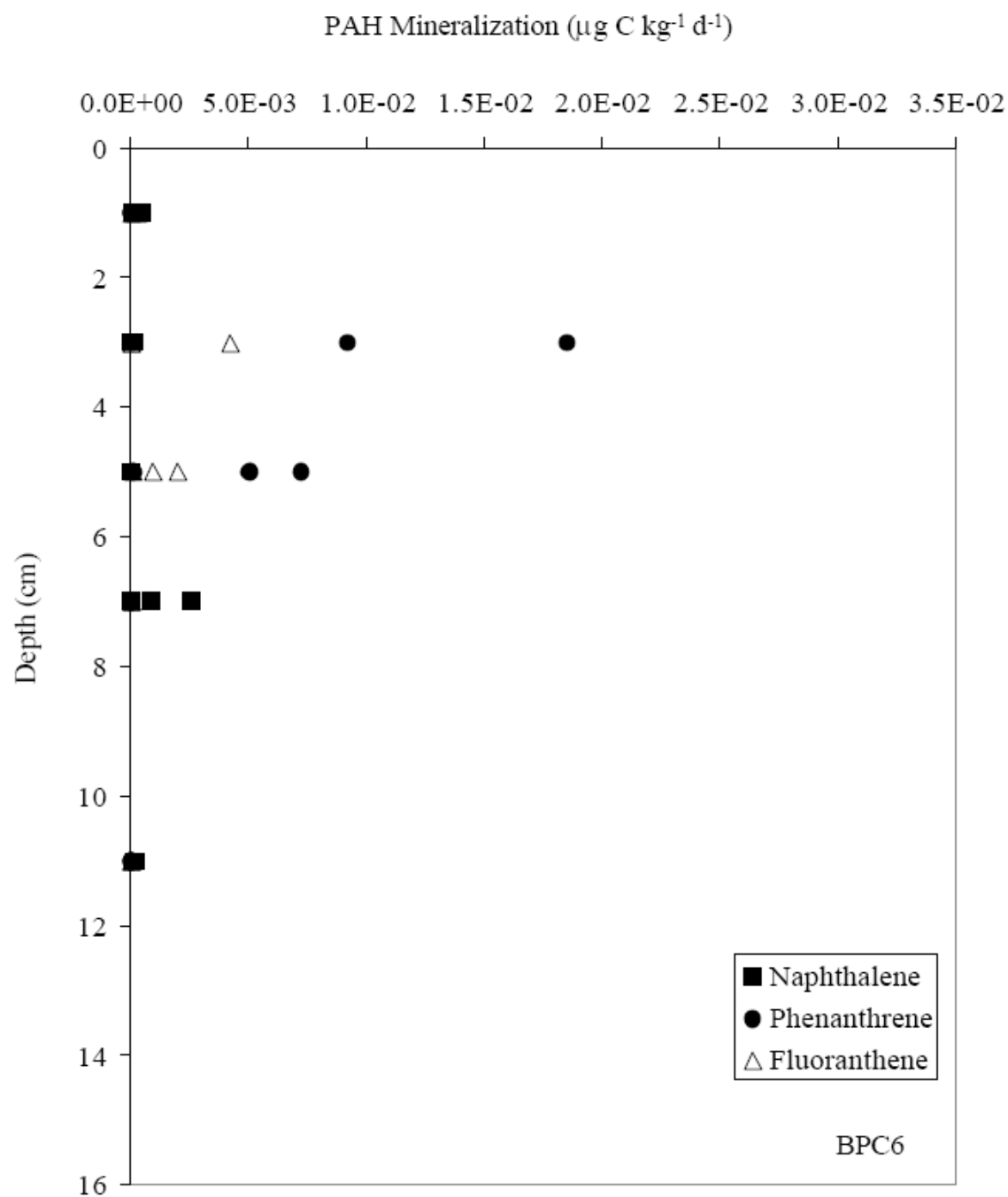


Figure 5-89. Mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) of the PAHs, naphthalene, phenanthrene and fluoranthene versus depth (cm) in core slices taken at station BPC6 in Bishop's Point, Pearl Harbor, HI.

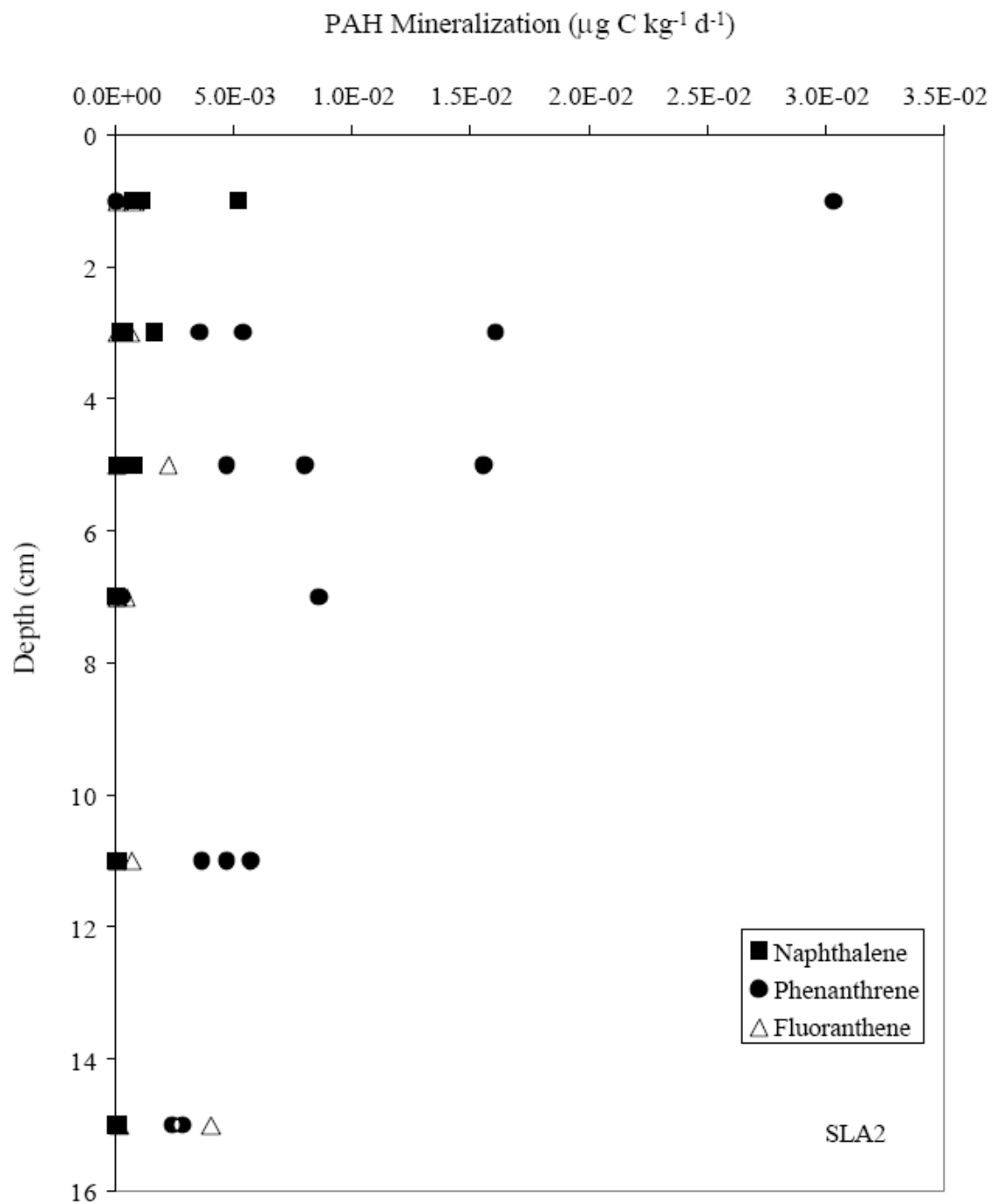


Figure 5-90. Mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) of the PAHs, naphthalene, phenanthrene and fluoranthene versus depth (cm) in core slices taken at station SLA2 in Southeast Loch, Pearl Harbor, HI.

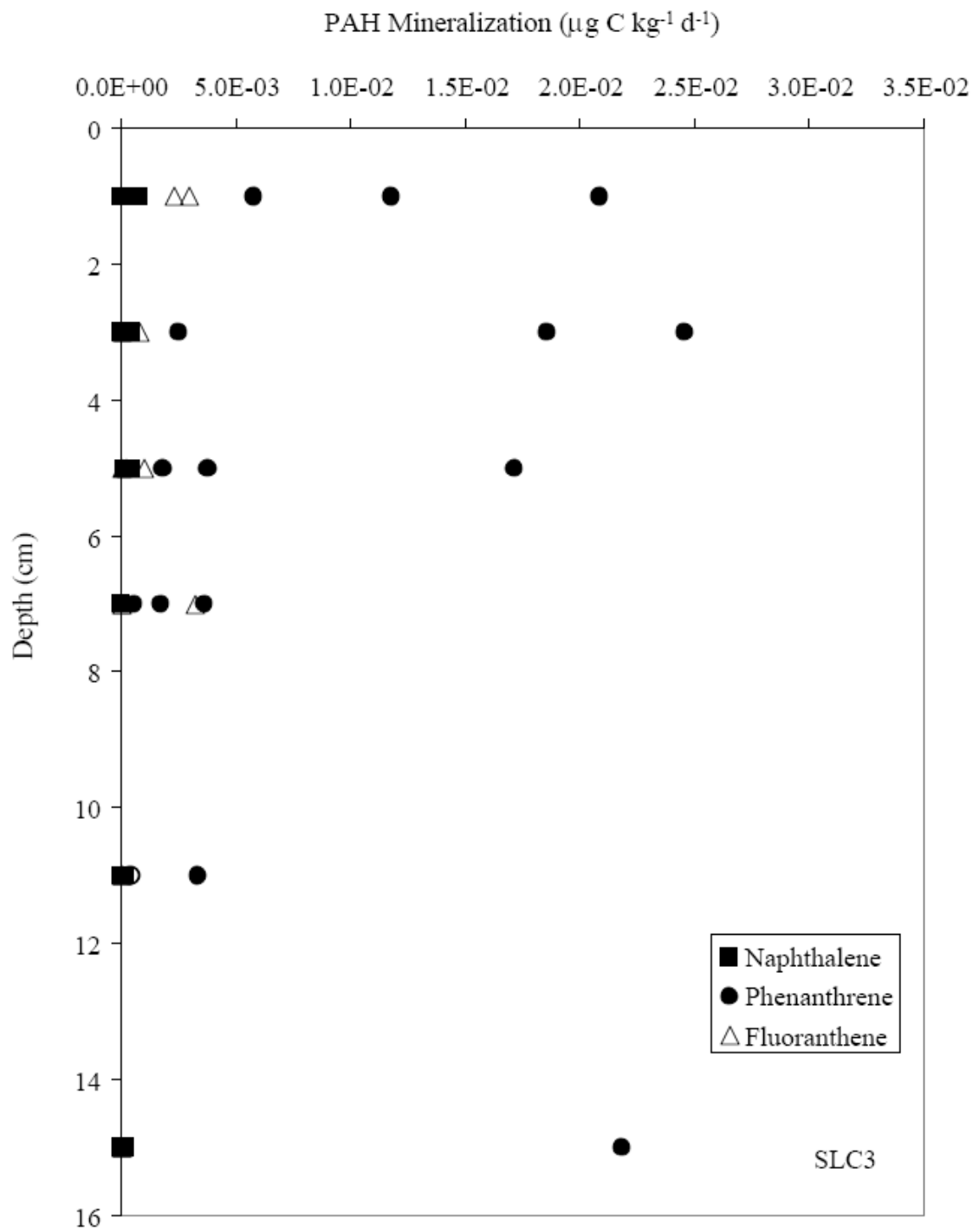


Figure 5-91. Mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) of the PAHs, naphthalene, phenanthrene and fluoranthene versus depth (cm) in core slices taken at station SLC6 in Southeast Loch, Pearl Harbor, HI.

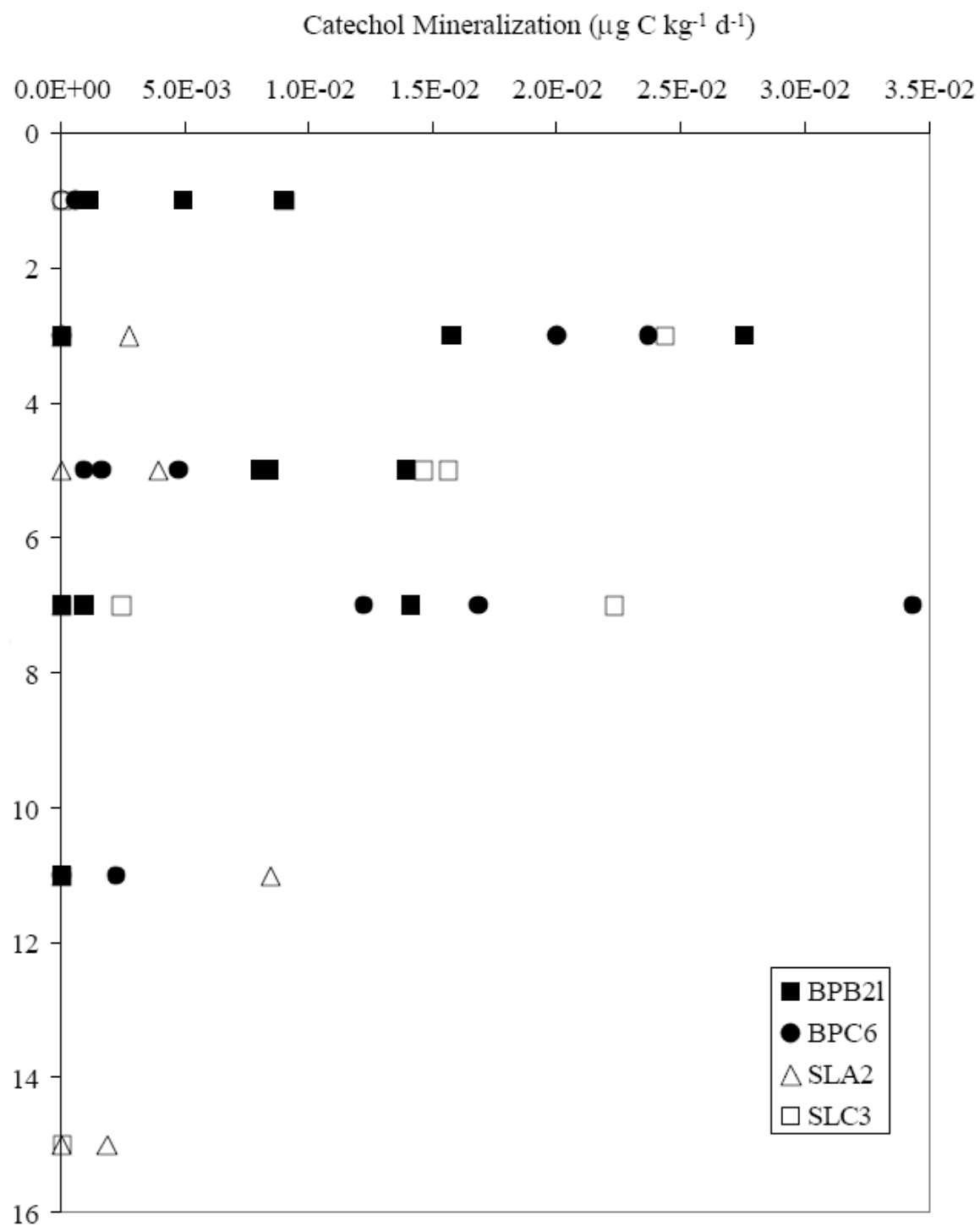


Figure 5-92. Catechol mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) versus depth (cm) in core slices taken at stations BPB2, BPC6, SLA2, and SLC6 in Pearl Harbor, HI.

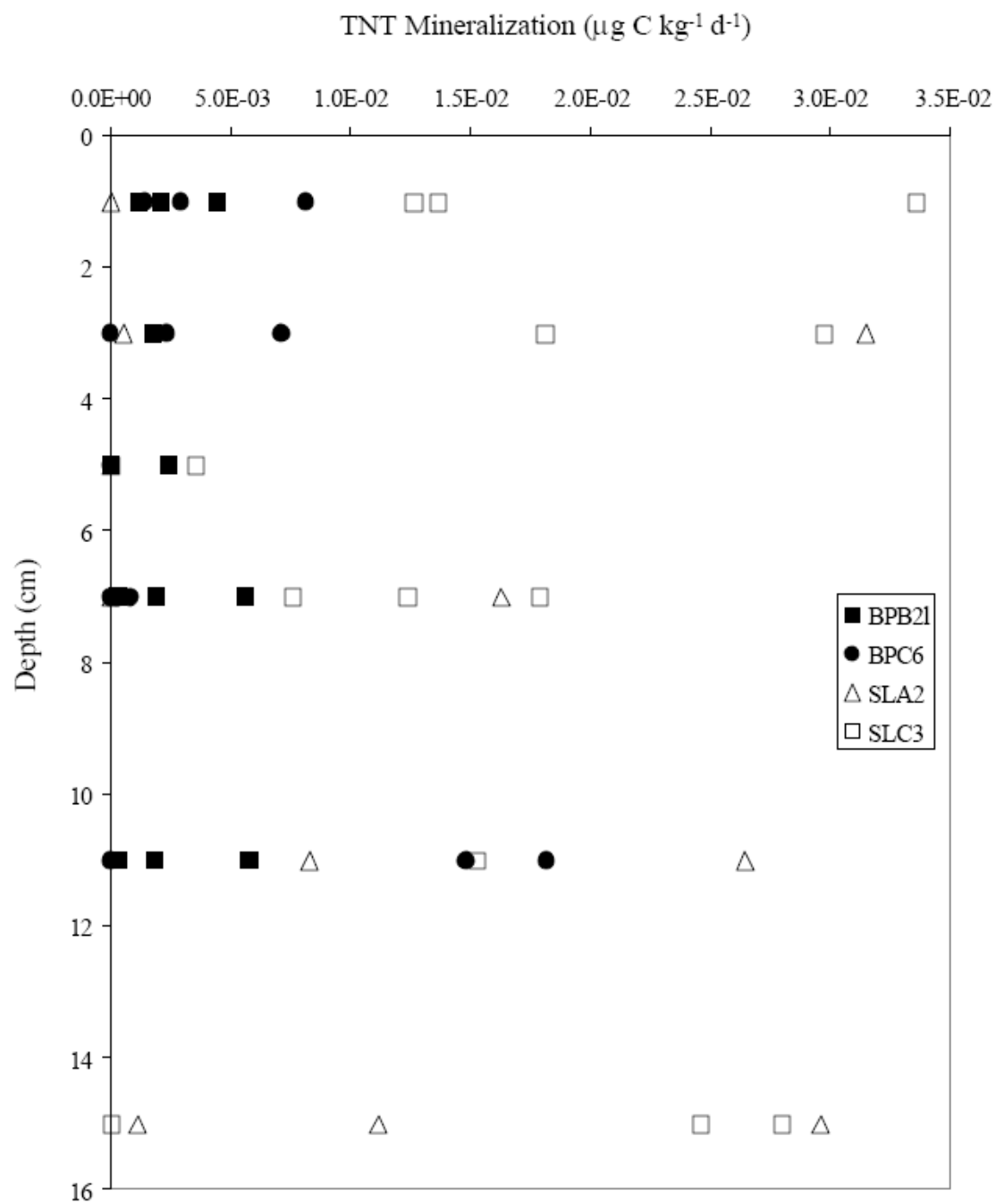


Figure 5-93. TNT mineralization ( $\mu\text{g C kg}^{-1} \text{ d}^{-1}$ ) versus depth (cm) in core slices taken at stations BPB2, BPC6, SLA2, and SLC6 in Pearl Harbor, HI.

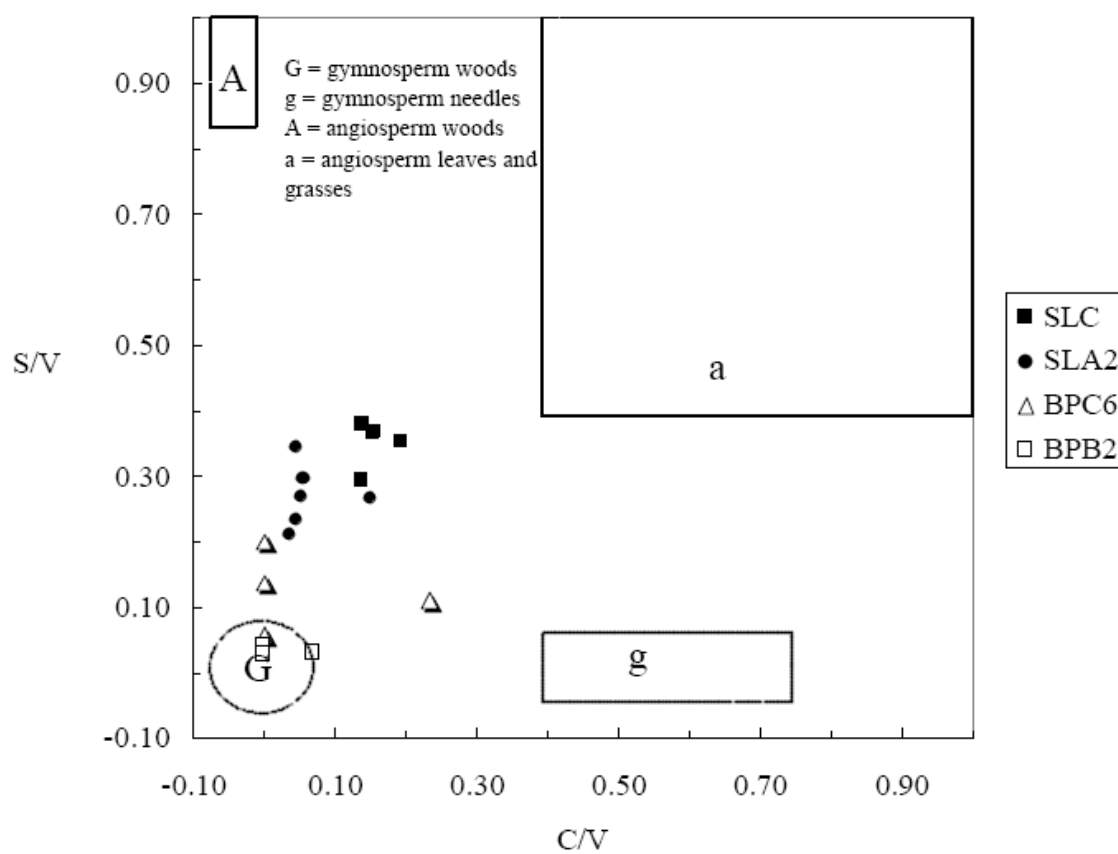


Figure 5-94. Lignin-derived phenol ratios (syringyl:vanillyl, S/V; cinnamyl:vanillyl, C/V) in core slices taken at stations BPB2, BPC6, SLA2, and SLC6 in Pearl Harbor, HI.

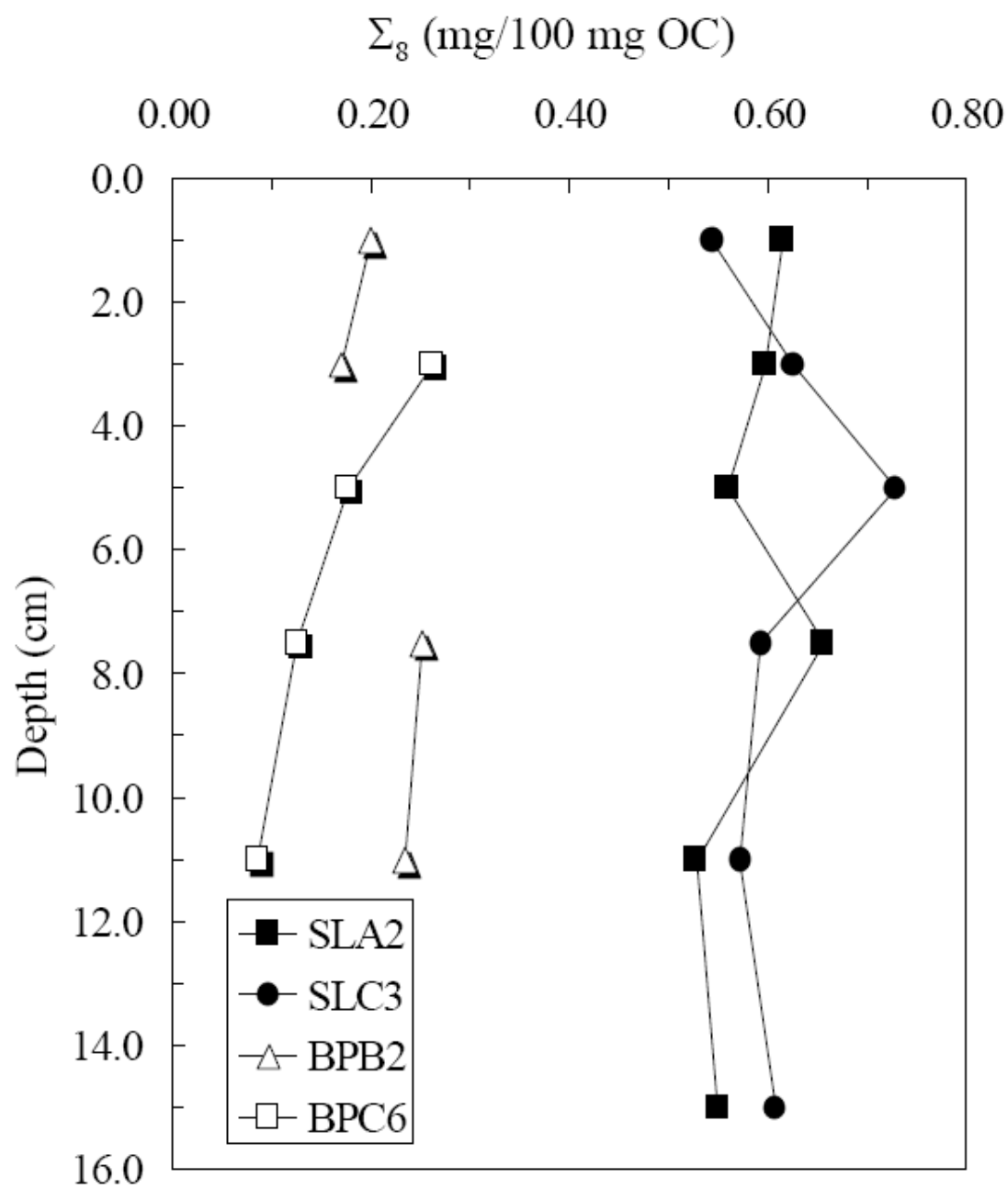


Figure 5-95. Organic carbon normalized lignin distribution ( $\Sigma 8$ , mg/100 mg OC) with depth in core slices taken at BPB2, BPC6, SLA2, and SLC6 in Pearl Harbor, HI.



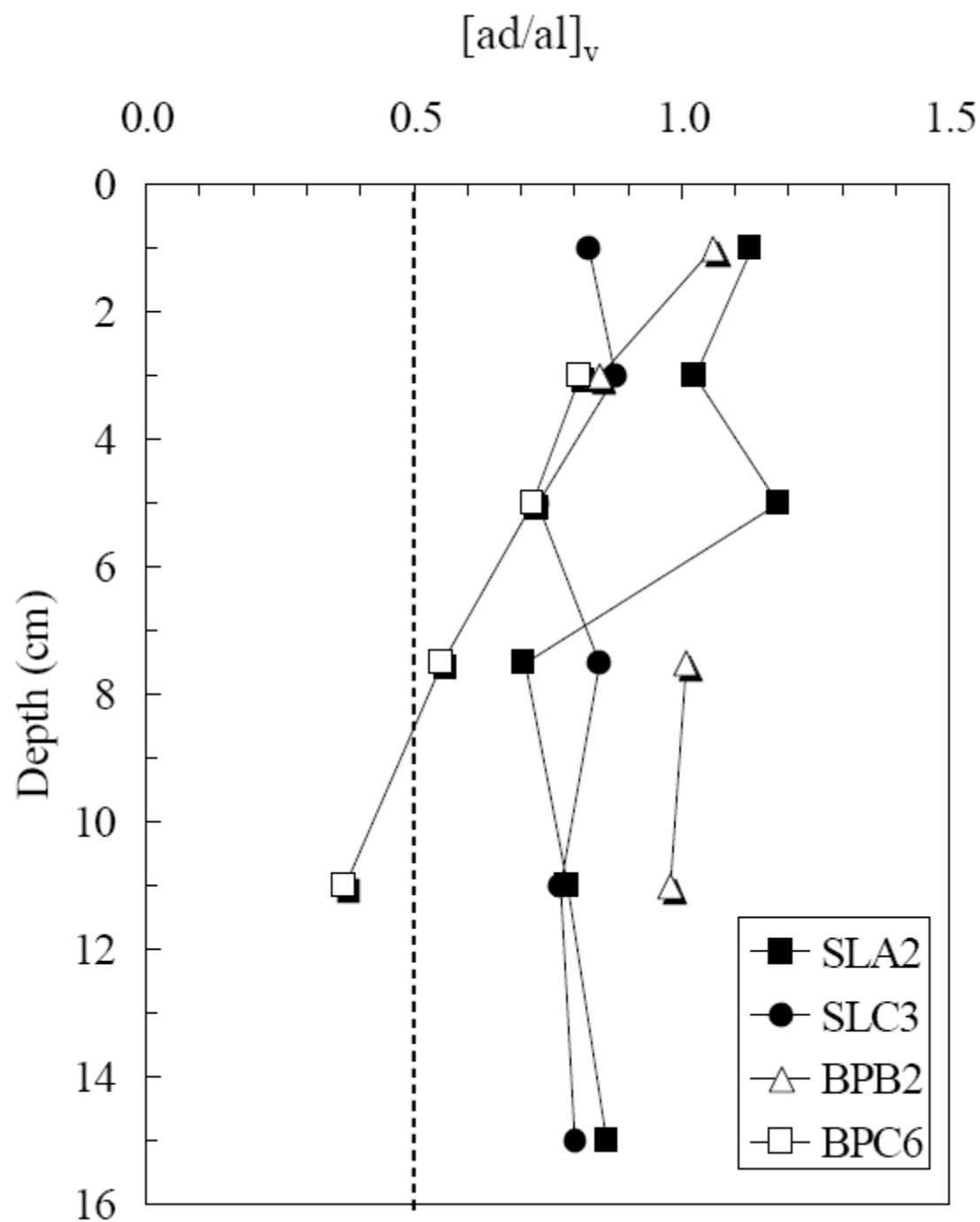


Figure 5-96. Ratio of acid to aldehyde phenolic moieties in the vanillyl family ( $[ad/al]_v$ ) versus depth in core slices taken at stations BPB2, BPC6, SLA2, and SLC6 in Pearl Harbor, HI.

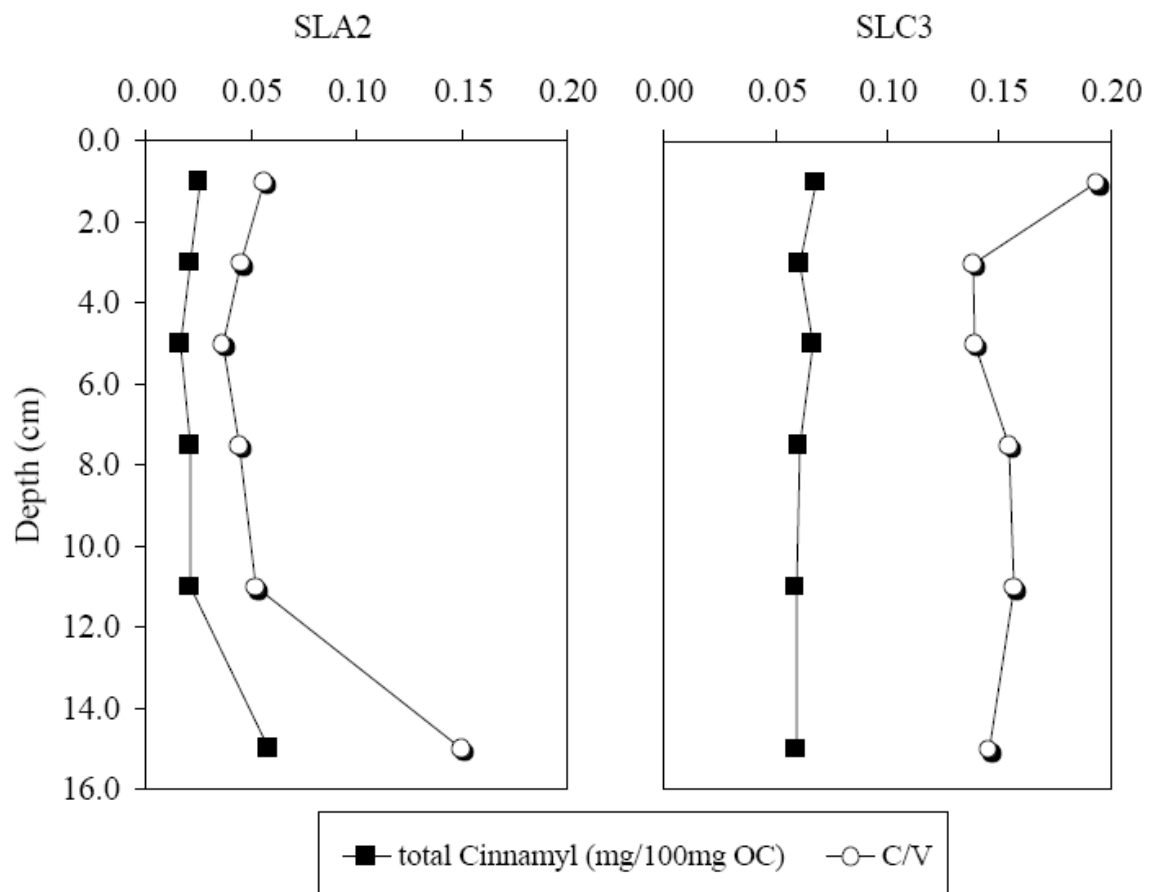


Figure 5-97. Concentration of cinnamyl phenols (mg/100 mg OC) and ratio of cinnamyl to vanillyl phenols (C/V) versus depth in core slices taken at the four stations in Pearl Harbor, HI.

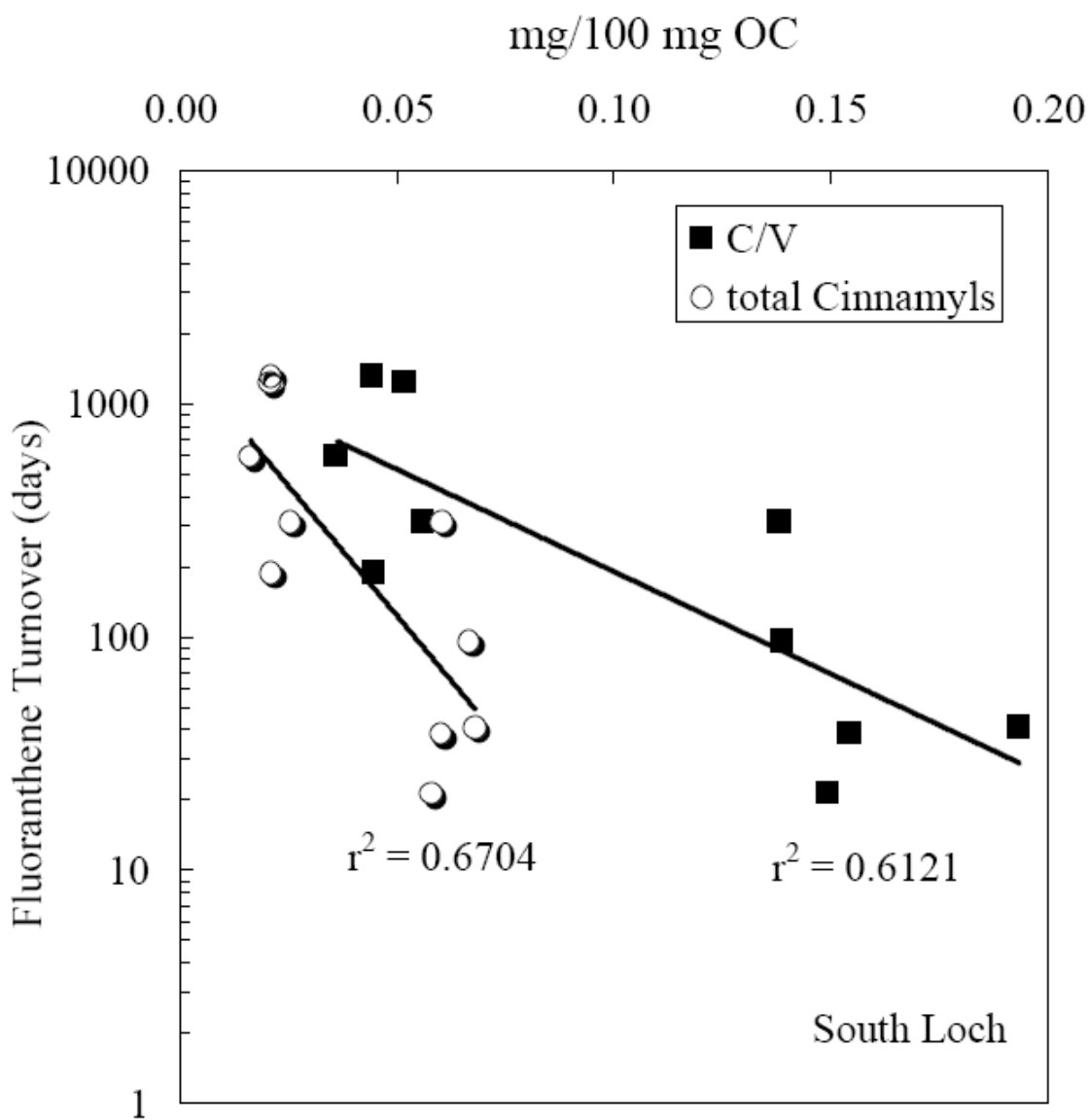


Figure 5-98. Relationship between fluoranthene turnover (days) and cinnamyl phenol concentration (mg/100 mg OC) and C/V ratio.

## 5.6 FIELD DEPLOYMENT OF VIMS SEA CAROUSEL

### Introduction

Pollutants from contaminated marine sediment that settled on the sea floor may have many ways to re-enter the water column above. As a consequence, an originally inactive source of pollutants may become active again and cause concern. The possible mechanisms that can carry pollutants away from their buried locations may include advection from ground water flow, pure diffusion within sediment, redistribution caused by bioturbation, and sediment erosion caused by physical forces. To evaluate the importance of each possible pathway, an index equation that represents all the possible processes has been proposed as follows.

$$\sum \text{flux} = F_{dc} + F_{dc} + W(C_o - C_H) + R_d H + E_{\text{eff}}$$

where  $F_{dc}$  is the chemical diffusion term,  $F_{dc}$  is the bioturbation term,  $W(C_o - C_H)$  is the ground water advection term,  $R_d H$  is the chemical degradation term, and the last term represents the net effect (or the effective erosion rate) from solid phase dynamics: erosion and deposition. This section concentrates on one of the solid phase dynamic processes, erosion, with a limited discussion on deposition. We started with the traditional approach on how to address the erosion rate, and then, tried to address the effective erosion rate with suggested approaches.

Considering the complexity of the natural marine environment, it is not a simple task to obtain a reliable estimation of each process mentioned above. *In-situ* measurements would be the best approach for obtaining this information because only an *in-situ* approach can minimize the possible error caused by changing experimental environments during sample transport to the laboratory.

The sediment erosion process itself is not a well-understood process yet because of the significant variations in sediment composition, consolidation history, ambient water conditions, and benthic bio-activities (Wright *et al.*, 1997). In other words, each system may have a different response because of the varying natural environments. Thus the best way to study sediment erosion characteristics is by carrying out *in-situ* experiments. All of the controlling factors should be the same for an *in-situ* experiment and the possibility of introducing an “artificial effect” is minimized. For this reason, we conducted the field experiments using the VIMS Sea Carousel (Maa *et al.*, 1993) to address sediment erosion behavior in Pearl Harbor.

## Methods

Two sites within Pearl Harbor (Bishop Point and SE Loch) were selected for in-situ erosion experiments (Figure 5-99). The local coordinates for Bishop Point are 1651777 and 59388. For the SE Loch site, the coordinates are 1658055 and 67916. Sediment samples collected from these two sites reveal that sediment at the Bishop Point (BP) site has more coarse material (37.8% clay, 34.2% silt, 26% sand, and 2% gravel) with a Total Carbon (TC) content around 11% and Organic Carbon (OC) content about 2.1%. At the SE Loch (SL) site, sediments are finer with more clay (46.4% clay, 36.4% silt, 15.7% sand and 1.5% gravel) but a slightly less TC content (8 %) and about the same OC content (2.8%). The clay minerals at BP and SL sites are mainly Mg-Calcite (42% and 60%, respectively), Aragonite (18% and 17%), Calcite (12% and 11%), Kaolinite (9.8% and 5.9%), mixture of Illite, Smectite, and Mica (9.6% and 2.9%), and Chlorite (3.6% and 0.9%).

Because the clay content at both sites is more than 30%, the erosion process is controlled by the electrostatic forces between clay particles rather than by gravitational forces. Note that the clay minerals in Pearl Harbor are very different with those in San Diego Bay, the first PRISM field site.

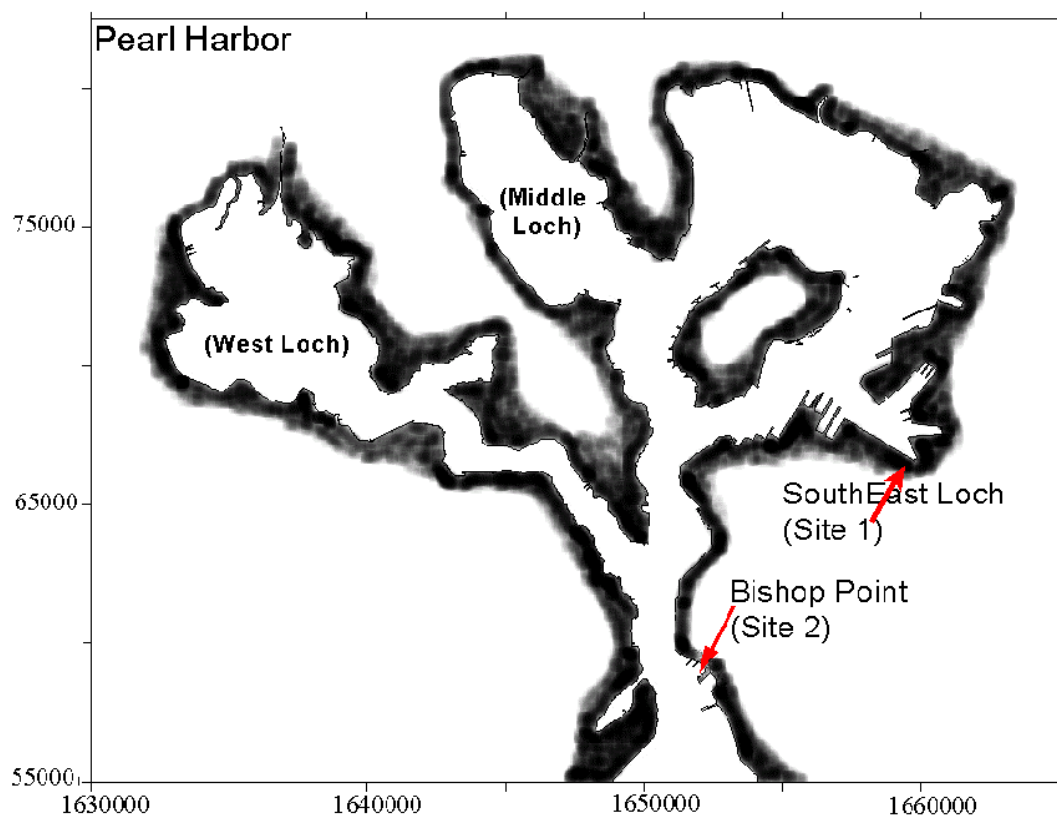


Figure 5-99. Deployment locations for the Sea Carousel in Pearl Harbor, HI.

The VIMS Sea Carousel (Figure 5-100) is an annular flume for field experiments. It has an inside diameter of 2.0 m and an outside diameter of 2.3 m. The cross section (width x height) is 0.15 m x 0.1 m. The driving force comes from a rotating ring on top of the flume. Response of the seabed (i.e., erosion), and consequently, the change in suspended sediment concentration (SSC) within the flume, were measured by two Optical Backscatter Sensors (OBS, Downing, 1983) mounted at the middle elevation of the inner wall.

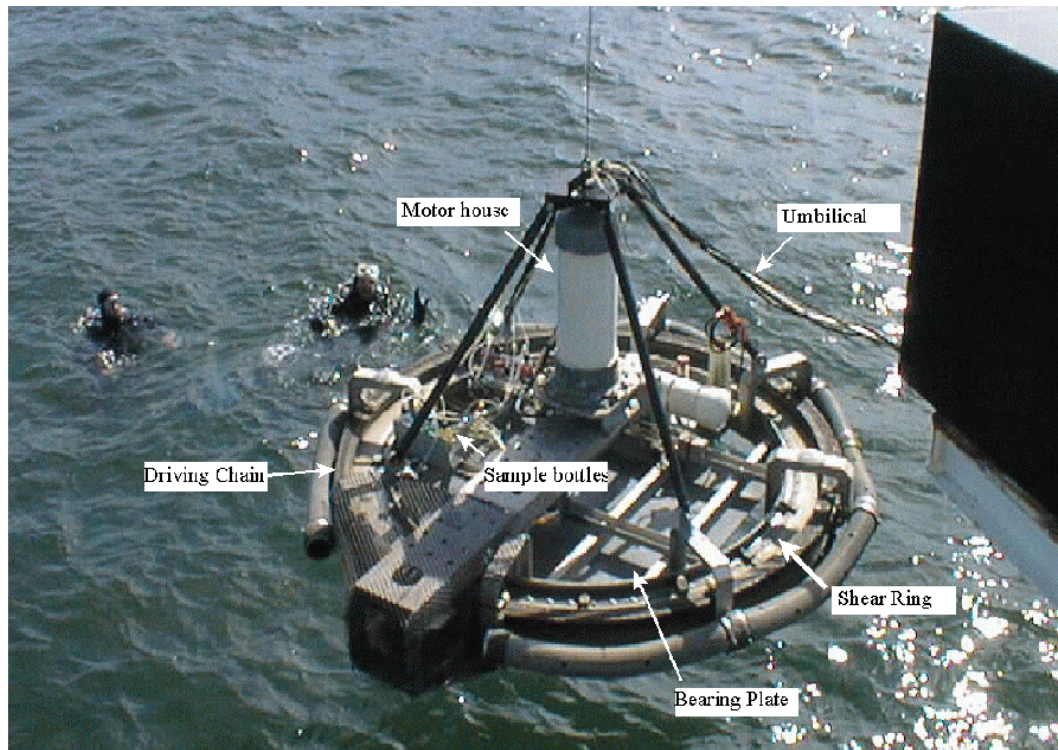


Figure 5-100. VIMS Sea Carousel during deployment.

The carousel was lowered into the water slowly to allow the build up of air pressure in the motor house to prevent water intrusion. The flume's own weight (about 200 kg in water) is used to penetrate into the sea floor and build up an annular flume. A bearing plate prevents the flume from sinking into soft mud beds. Deployment of the carousel is usually carried out during a slack tide with care not to seriously disturb the bottom fluffy sediment.

The spatial-averaged bed shear stresses,  $\tau_b$ , caused by the rotating ring can be calculated as  $\tau_b = 0.0114 \Omega^{1.693}$ , where  $\tau_b$  is in Pascal ( $\text{N/m}^2$ ) and the ring speed ( $\Omega$ ) is in rpm (Maa, 1993; Maa *et al.*, 1995). The actual ring speed was calibrated with the motor controller's speed readings before deployment. The maximum spatial variation of  $\tau_b$  is about 15% of the average value at a large averaged bed shear stress, 0.8 Pa.

Two OBS' (OBS and OBSN) were used and *in-situ* calibrations were carried out because the response of OBS is very sensitive to the grain size in suspension. Water samples for calibrating the OBS were taken while the carousel was in operation. Details of the *in-situ* OBS calibration

procedures were given in Maa *et al.* (1993). Calibration results of these two OBS' at the Bishop Point site are given in Figure 5-101. At the SE Loch site, however, the *in-situ* calibration was not successful because the TSS concentrations at high bed shear stresses were too high, and clogged the sampling pipe. Thus, they were calibrated again in the laboratory using the sediment samples collected at the site. By comparing the two OBS' readings at low bed shear stresses from both *in-situ* and laboratory calibration results, estimated *in-situ* calibration equations for the SE Loch site was obtained (Figure 5-102).

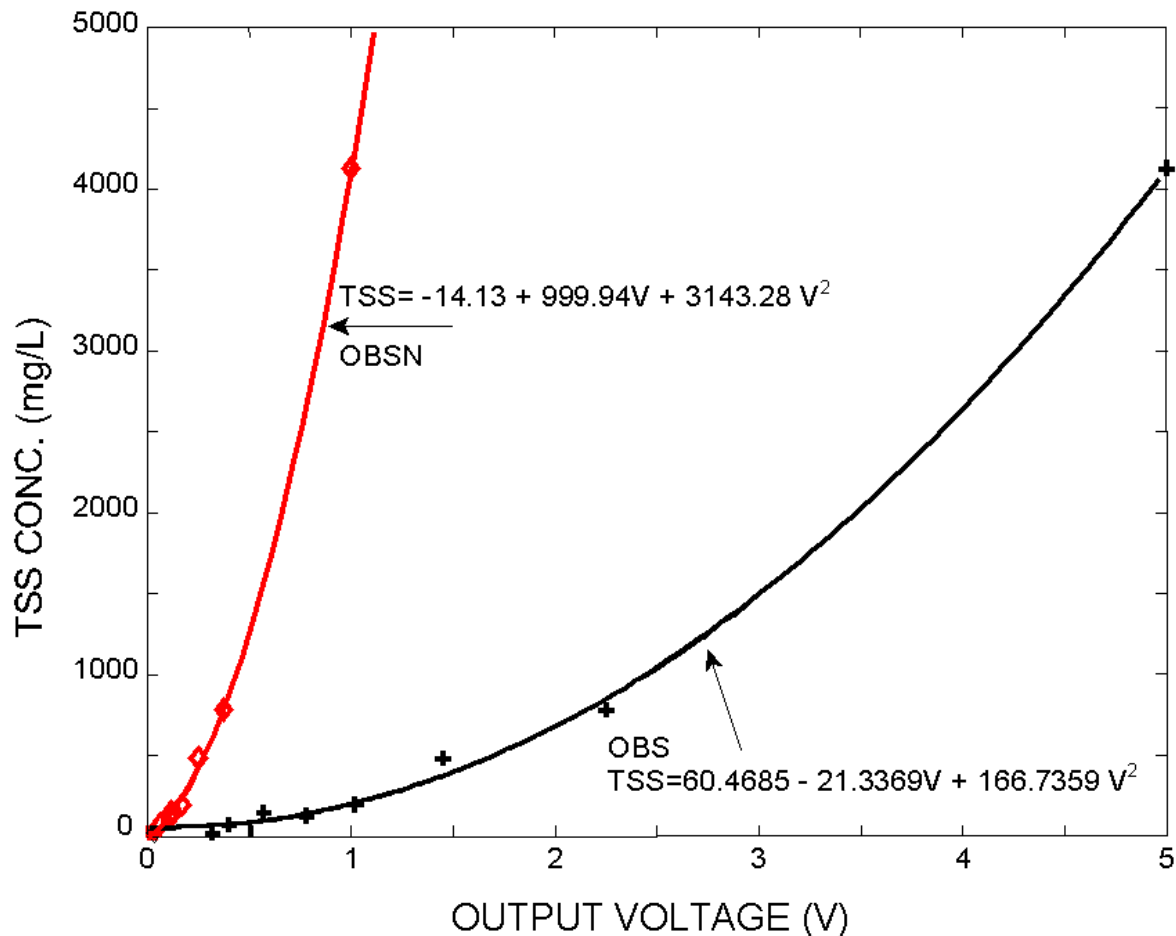


Figure 5-101. OBS and OBSN calibration curves for Bishop Point.

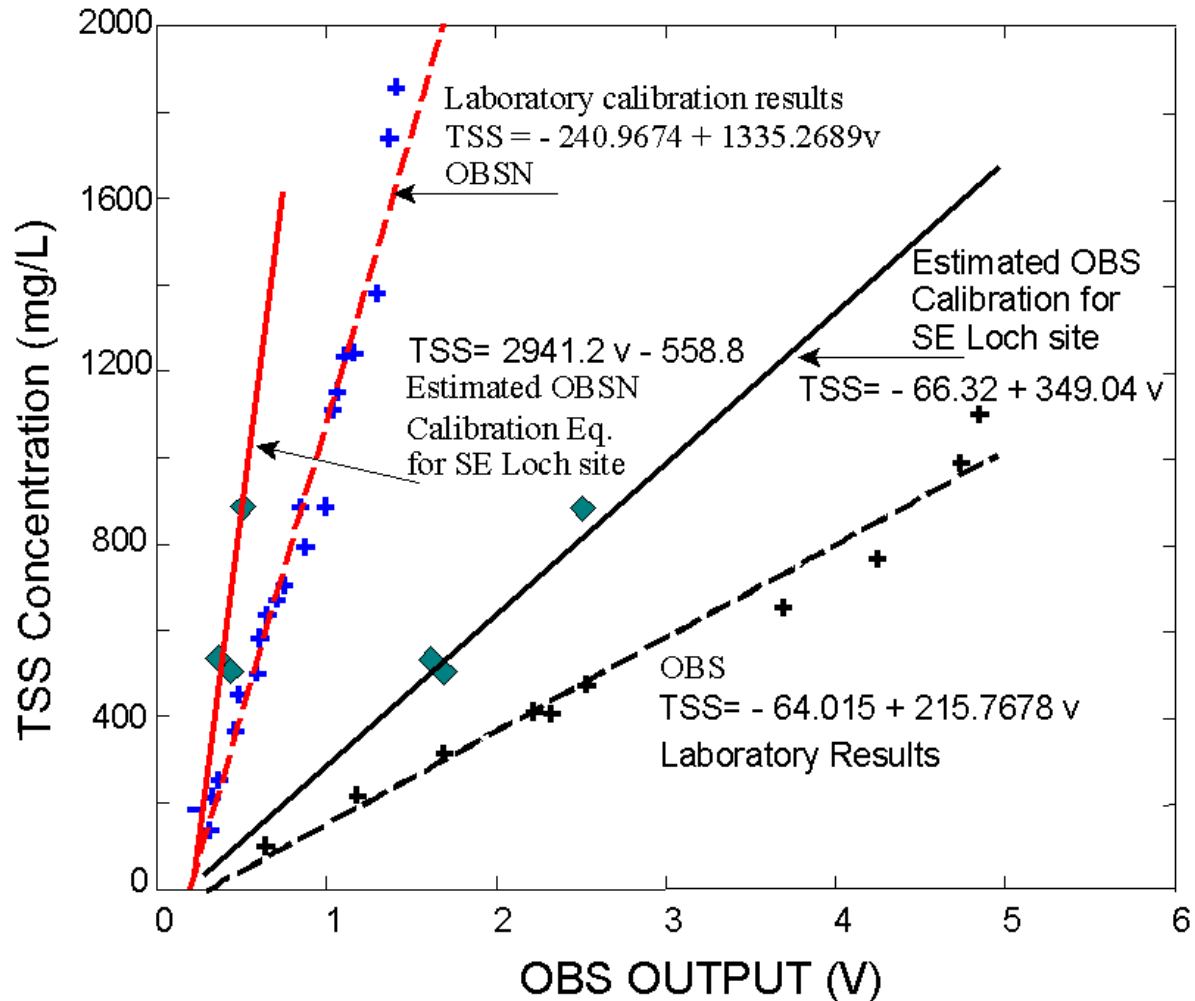


Figure 5-102. Estimation of the OBS calibration equations for the Southeast Loch site.

In the laboratory calibration, sediment samples were mechanically mixed for uniformity using a pump, and then the OBS sensors were inserted into the sediment slurry to check the OBS readings. Because of the strong shear in the pump, the size of sediment floc is about the same for all the concentrations. Thus, straight lines were obtained (Figure 5-102). In a field calibration, however, sediment suspended from bottom may become bigger and bigger because of higher erosion resistance. Thus, curved lines were obtained from *in-situ* calibration (Figure 5-101).

Nevertheless, the OBS responses are quite different at these two sites. Because the suspended sediment particles are much finer at the SE Loch site, the maximum TSS concentration that the OBS can effectively measure reduced to about 2000 mg/L.

There are two types of tests at each site: an incipient test and an erosion rate test. The incipient test is aimed at determining the critical bed shear stress at the water-sediment interface. The



Erosion rate test is designed to address the erosion rate for a given excess bed shear stress and find the possible maximum erosion resistance.

We have completed many field deployments in both the Upper (Maa, *et al.*, 1998) and Lower Chesapeake Bay sites (Maa and Lee, 1997), on the inner shelf of the Atlantic Bight near Duck, North Carolina (Maa *et al.*, 1993), and in the Anacostia River (Maa *et al.*, in prep.). These experiments have shown that the VIMS Sea Carousel is a reliable instrument for carrying out field experiments in shallow water areas (up to 20 m). It is possible to do this kind of experiment at a water depth up to 50 m without major modifications.

## Results

### Critical Bed Shear Stress at Sediment Surface

The incipient test starts with a small  $\tau_b$  and uses a small increment of  $\tau_b$  (e.g.,  $\tau_{b1} = 0.02$  Pa and  $\Delta\tau_b < 0.02$  Pa) to identify the critical bed shear stress ( $\tau_{cr}$ ) at the water-sediment interface,  $z = 0$ . All the operation parameters (ring speeds and durations) were pre-programmed and only minor modification was possible during the experiment. Details of the criterion for selecting the critical bed shear stress have been presented in the previous annual report, and thus, are not repeated here. The details can also be found in Maa and Lee (1997), and Maa *et al.* (1998).

Figure 5-103 shows the results of our measurement of the critical bed shear stress,  $\tau_{cr}$ , at the sediment surface at BP site. The first bed shear stress, 0.022 Pa, although small, stirred up the limited surficial fluff and caused a rise in the TSS reading (Figure 5-103a). The readings, however, approach a plateau at the end of this small bed shear stress. The next eight higher bed shear stresses, from 0.026 to 0.12 Pa, only increased the TSS slightly, not enough to be deemed significant. Only when the bed shear stress increased to about 0.14 Pa, was a clear increase of TSS noticed. Thus, we selected the average bed shear stress, 0.13 Pa, as the  $\tau_{cr}$  for incipient motion at bed-sediment surface for this site.

After the experiment for measuring  $\tau_{cr}$  at the sediment surface was done, we immediately began the experiment for measuring the erosion rate. We will show the details of the erosion rate experiment later. The deployment of the VIMS Sea Carousel was not as smooth as it could be because of the significant bed surface irregularity as a lot of debris was found to be deposited at this site. Actually, we have tried three times to find a suitable site for deploying the flume. For this reason, the two experiments took all the time we had, and thus, there was no duplication at this site.

The incipient erosion experiment carried out at SL Site shows quite different results (Figure 5-104). The first  $\tau_b$  (0.022 Pa) also stirred up surficial fluff, but it started decreasing at the middle of this first  $\tau_b$  and continued to decrease until the end of second  $\tau_b$ . The 3rd  $\tau_b$  seemed capable of stirring sediment again, but it eventually ceased and the same TSS remained until the end of 5th  $\tau_b$ . A significant rise of the TSS reading at the 6<sup>th</sup>  $\tau_b$  (0.8 Pa) and further increase of TSS for the rest  $\tau_b$ 's indicate that the critical bed shear at the water-sediment interface was 0.07 Pa.

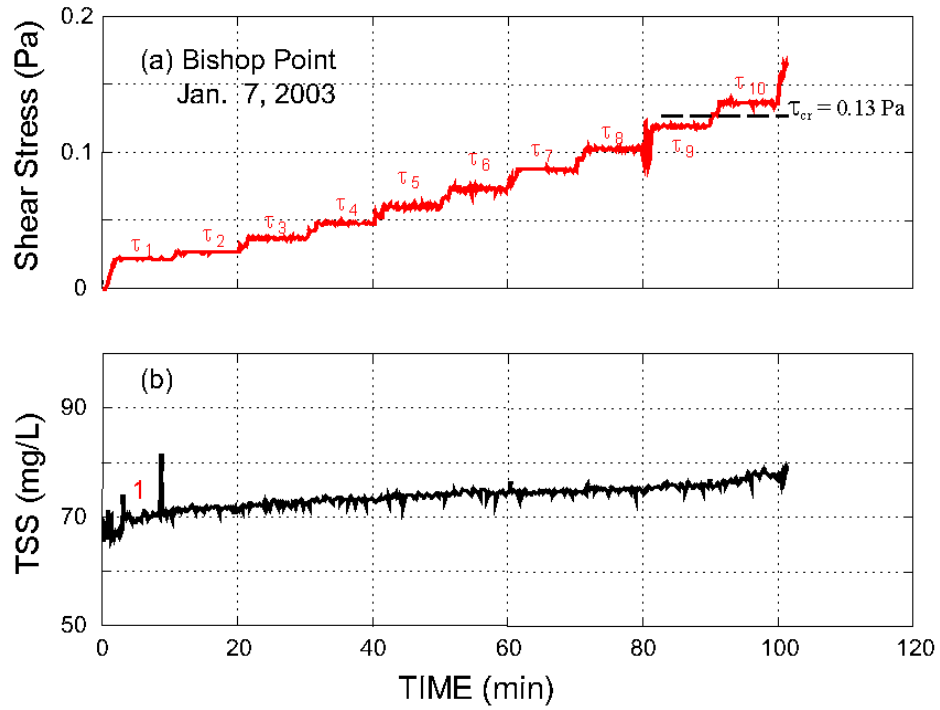


Figure 5-103. Experiment to measure the critical bed shear stress at the bed surface for the Bishop Point site.

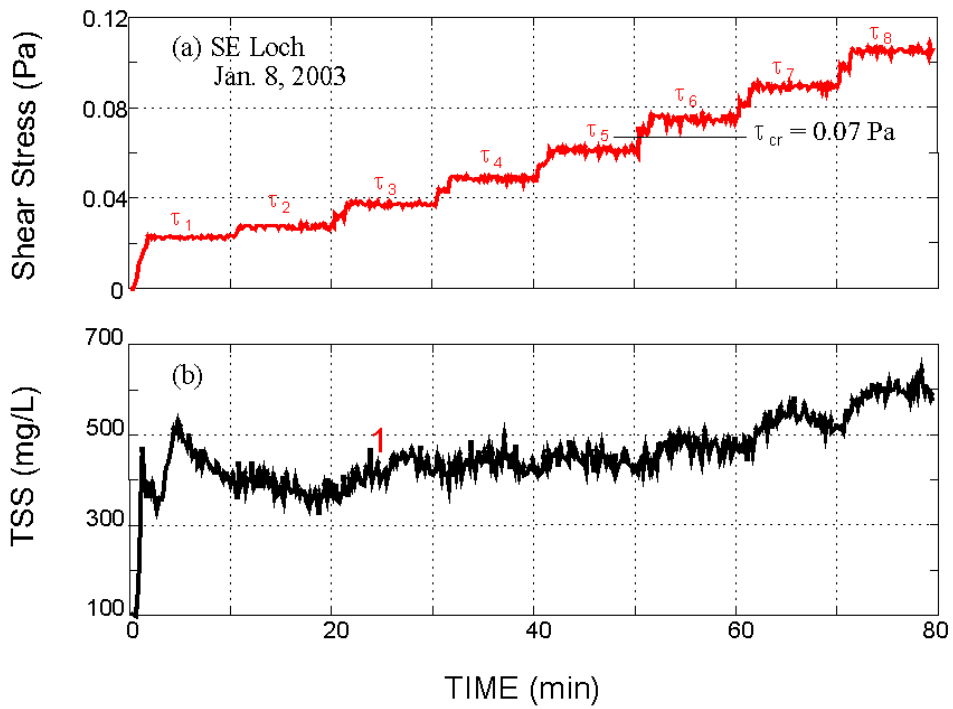


Figure 5-104. Experiments to measure the surface critical bed shear stress at the Southeast Loch site.

### Erosion Rate Experiments

The erosion rate test starts with a relatively large  $\tau_b$  and uses a large and unequal  $\Delta\tau_b$  (e.g.,  $\tau_{b1} = 0.2$  Pa and  $0.05 < \Delta\tau_b < 0.2$  Pa) to find erosion rates. Details of the method for finding the erosion rates were given in the last annual report, and thus, are not duplicated here.

For the erosion rate experiment conducted at Site BP, the Flume was deployed using a land-based crane because this site is close to a quay wall. After deployment, the control and monitoring was performed within a utility truck parked nearby. After the experiment, the flume was left on the seafloor for overnight and retrieved the next morning for deployment at SE Loch. Details of the applied shear force and bed response observed by the OBS are given in Figure 5-105.

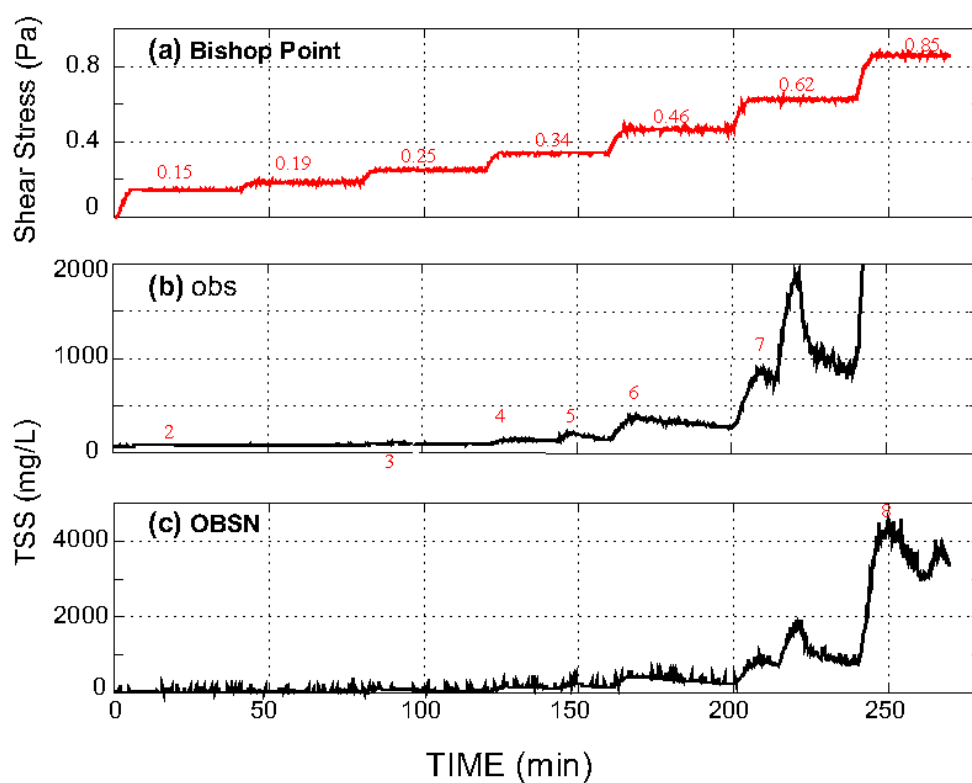


Figure 5-105. Bed shear stresses and bed responses during the erosion test at the Bishop Point site. Numbers in the shear stress diagram are the average bed shear stresses.

A noticeable feature at this site is that the TSS concentration had a large pulse response during a constant  $\tau_b = 0.62$  Pa. At elapse time = 215 minutes, the TSS jumped from about 800 mg/L to almost 2000 mg/L. This high TSS did not remain for long, it fell back to around 1000 mg/L in about 15 minutes. A reasonable explanation of this behavior may be attributed to a thin layer of more easily erodible sediment that was exposed at that particular time. If so, the sediment in this thin layer must be also very fine material, and must have leaked out easily and caused a significant signal on the OBS output.

Because we have two OBS sensors with different sensitivities to obtain more data for estimating the erosion rate, there is no need to add another experiment unless for the purpose of checking the repeatability. The experiments carried out in the San Diego Bay proved that our experiment is repeatable. There is no need to repeat the experiment except we have extra time.

Unfortunately, due to one reason or the other, we ran out of time for using the lifting equipment required to do the duplicate test. Nevertheless, the data acquired were sufficient to understand the erosion rate at the Pearl Harbor.

The first attempt to carry out the experiment at the SE Loch site failed because of the extremely soft sediment at that site. We spent about 3 hours before we finally obtained a good deployment. Results of the erosion rate experiment are given in Figure 5-106. The easily erodible sediment layer seems to also exist at this site, although the amount is much smaller (see the response at elapse time = 95 minutes). The OBS with high sensitivity was saturated at elapsed time = 125 minutes. Because we have a less sensitive sensor, we could continue the experiment and obtained enough data.

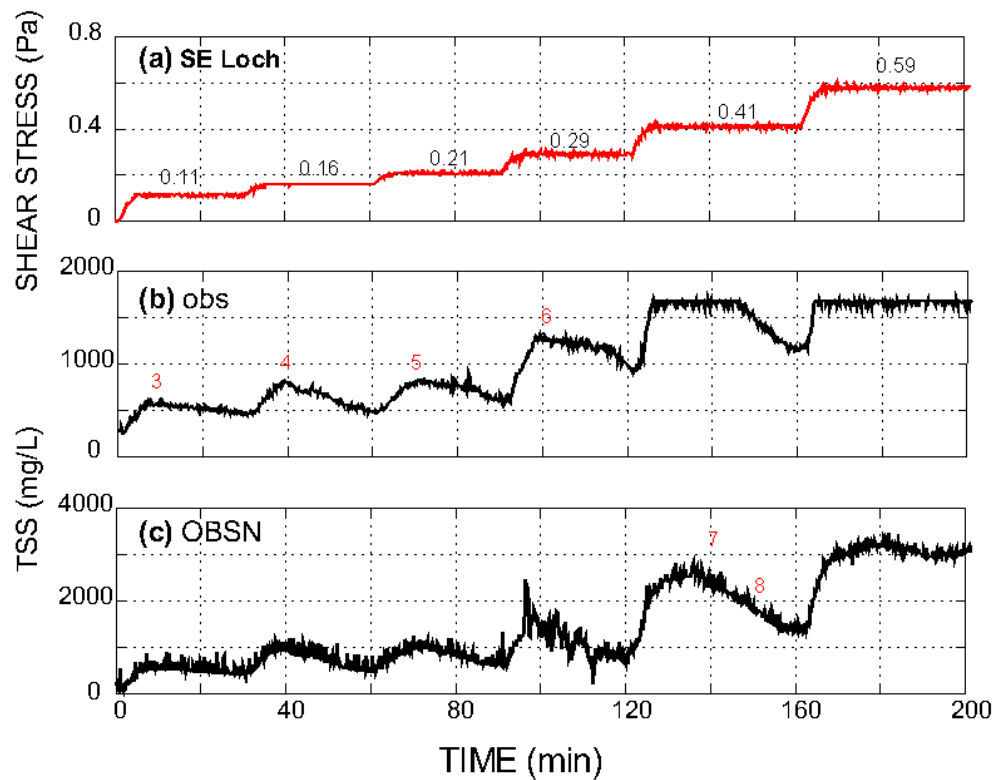


Figure 5-106. Bed shear stresses and bed responses during the erosion test at the Southeast Loch site. Numbers in the shear stress diagram are the average bed shear stresses. Numbers in the OBS plots indicate when water samples were taken.

## Erosion Data Analysis and Results

A general pattern observed from the erosion rate experiments was that within a constant  $\tau_b$ , the TSSC increased for the first several minutes and then decreased. This phenomenon was also observed in other tests carried out in the Lower Chesapeake Bay (Maa *et al.*, 1993; Maa and Lee 1997, Maa *et al.*, 1998), Anacostia River (Maa, 2002). This phenomenon can be described using the equation below, which shows the change of TSSC as the result of a decreasing resuspension rate with time (Yeh, 1979; Fukuda and Lick, 1980) and a constant leakage of water from the rotating ring (Lee, 1995).

$$Ah \frac{dc}{dt} = AE_o e^{-\lambda t} - c(t)Q_L$$

where A (10132 cm<sup>2</sup>) is the area covered by the VIMS Carousel, h = 10 cm is the channel depth, c is the TSS concentration in g/cm<sup>3</sup>, t is time in seconds, Q<sub>L</sub> is the leakage rate of water in cm<sup>3</sup>/sec, E<sub>o</sub> is a erosion rate constant (in g/cm<sup>2</sup>/sec), and  $\lambda$  is a time rate constant (in sec<sup>-1</sup>).

The leakage was caused by the dynamic pressure difference and the imperfect sealing between the rotating ring and the two sidewalls. Since the dynamic pressure is induced by the rotating ring, it is related to the ring speed (*i.e.*,  $\tau_b$ ). Therefore the leakage rate can be assumed as a constant for a given constant  $\tau_b$ . Lee (1995) showed that the distribution of suspended sediment is almost uniform within the flume for fine-grained sediment. Thus, the leakage of sediment mass can be described as the last term in the equation.

The time-decreasing erosion rate (first term on the right side of the equation) is the typical "Type I" erosion behavior observed in many laboratories as well as in field experiments for fine-grained sediments (Parchure and Mehta, 1985; Amos *et al.*, 1992). The equation indicates that the TSSC will increase ( $dc/dt > 0$ ) if the amount of sediment eroded is larger than the leakage. Otherwise, the TSSC will decrease. The equation has an analytical solution as  $c = -k_1 e^{-\lambda t} + k_2 e^{-\beta t}$ , where  $k_1 = \gamma/(\lambda - \beta)$ ,  $\gamma = E_o/h$ ,  $\beta = Q_L/(Ah)$ ,  $k_2 = k_1 + c_i$ , and  $c_i$  is the initial concentration for a given constant  $\tau_b$ . In the above equation, there are three unknown parameters: E<sub>o</sub>,  $\lambda$ , and Q<sub>L</sub>, which define the erosion process and the leakage rate. To estimate these unknown parameters, least-square fitting techniques using the Nelder-Mead simplex method (Dennis and Woods, 1987) for a nonlinear equation was selected to fit the N concentration data points ( $c_i$  and  $t_i$ ,  $i = 1, 2, \dots, N$ ) within a constant bed shear stress. Details of this method can be found in Maa and Lee (1997).

The results of all the data analysis are summarized in Table 5-27 and Figure 5-107. The time constant,  $\lambda$ , varies between 0.001 and 0.009 and has an average of 0.005 s<sup>-1</sup> (Figure 5-107b). This is an indication that erosion is a fast process because  $\exp(-\lambda t)$  approaches zero with  $\lambda = 0.005 \text{ s}^{-1}$  and  $t > 1500$  seconds (25 minutes). Thus, the erosion process can be considered to have ceased at the end of all the applied bed shear stresses given in our field experiments. For this reason, the difference between any two successive bed shear stresses given in the third column of Table 5-27 is the excess bed shear stress,  $\tau_{ex}$  and the measured E<sub>o</sub> is the erosion rate,  $\epsilon$ , for the  $\tau_{ex}$ . The relationship between  $\epsilon$  versus  $\tau_{ex}$  is summarized in Figure 5-107a.

As mentioned before, the sediment in the SE Loch site was so soft that it caused troubles during the flume deployment. This feature is also reflected in the erosion rate. Comparing these two sites, the sediment erosion rate at the SE Loch site was an order of magnitude higher than that at the Bishop Point site. As the top sediment was eroded, the erosion characteristics for the bottom sediments became closer and closer because of the long-term consolidation. Eventually the characteristics will be the same at a deep enough position.

Table 5-27. Results of in-situ erosion rate experiments.

Station	Sequence	Shear Pa	$E_o$ $\text{g cm}^{-2} \text{ s}^{-1}$	$\lambda$ $\text{s}^{-1}$	$Q_L$ $\text{Cc s}^{-1}$
Bishop Pt	1	0.13			
Bishop Pt	2	0.145	0.00000031	0.00361	0.988
Bishop Pt	3	0.185	0.00000028	0.00590	2.214
Bishop Pt	4	0.251	0.00000309	0.01251	6.862
Bishop Pt	5	0.337	0.00000432	0.00609	17.224
Bishop Pt	6	0.465	0.00002395	0.00863	18.581
Bishop Pt	7	0.623	0.00002986	0.00093	94.233
Bishop Pt	8	0.858	0.00031205	0.00605	64.916
SE Loch	1	0.07			
SE Loch	2	0.113	0.00003806	0.01040	15.641
SE Loch	3	0.159	0.00003022	0.00570	46.708
SE Loch	4	0.210	0.00002004	0.00364	34.634
SE Loch	5	0.290	0.00006031	0.00683	21.858
SE Loch	6	0.410	0.00010777	0.00468	45.851
SE Loch	7	0.578	0.00018624	0.00953	3.706

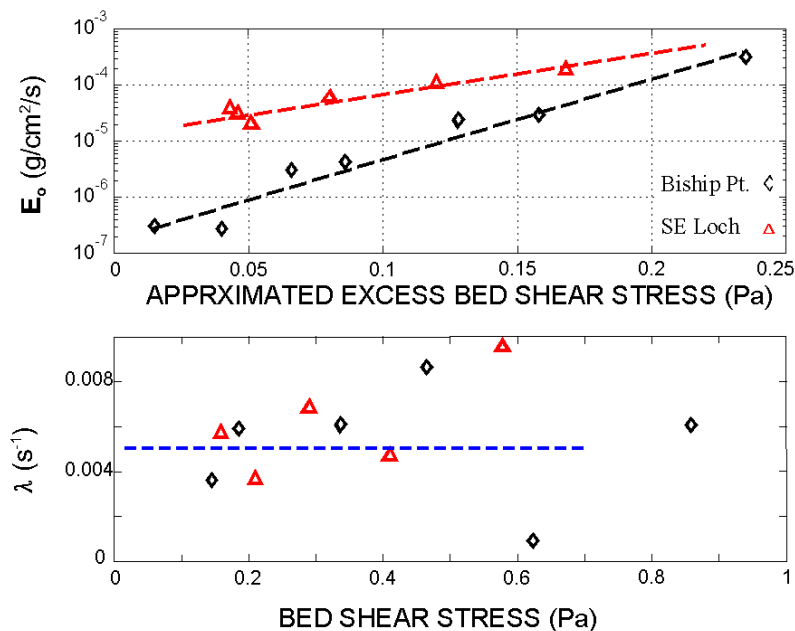


Figure 5-107. Summary of results for in-situ erosion rate experiments at P04 and P17.

## Discussion

The traditional studies of sediment erosion indicate that the erosion rate,  $\varepsilon$ , varies with the excess bed shear stress,  $\tau_{ex} = \tau_b - \tau_{cr}$ , where  $\tau_b$  is the bed shear stress caused by fluid motion, and  $\tau_{cr}$  is the critical bed shear stress for sediment erosion. Notice that  $\tau_{cr}$  is mainly a property of sediment and only changes slightly with the ambient pore water chemical conditions. For non-cohesive sediment, *e.g.*, fine sand,  $\tau_{cr}$  only vary slightly in the vertical direction, and its value can be estimated using the Shields diagram based on grain size. For cohesive sediments, however,  $\tau_{cr}$  can vary significantly in the vertical direction, especially near the water-sediment interface. For example, our experiments at the Bishop site indicated that  $\tau_{cr} \approx 0.13$  Pa at the initial water-sediment interface. As erosion proceeds with higher bed shear stresses, it only takes 15 to 25 minutes to achieve equilibrium states. This implies that  $\tau_{cr}$  can increase to more than 0.5 Pa easily within only 1 cm below the original interface.

For a tidal dominant flow, Maa and Kim (2000) suggested that (1) the erosion rate could be selected as a constant to simulate the erosion process because of the fact that tidal erosion is always near-equilibrium, and (2) tidal flows can only cause erosion during tidal acceleration phases because of a small positive  $\tau_{ex}$  in that period of time. Erosion stops during slack tides and tidal deceleration phases because of a zero or a negative  $\tau_{ex}$ . The above suggestion has been further implemented in a numerical studying of the TSS distribution in the York River successfully.

For a deposition-dominant environment, *e.g.*, a semi-enclosed basin like the San Diego Bay and the Pearl Harbor, tidal current is usually too weak to cause erosion. Even the simplified constant erosion rate model suggested in the previous paragraph may only contribute to a negligible small portion of the time. As a matter of fact, the tidal current measurement in the San Diego Bay suggested that erosion could not occur if tidal force is the only erosion force. Only when there is a large enough vessel passing through the specified location, the vessel propeller would cause erosion. Thus, the occasional occurrence of propeller wash is more important for finding the effective erosion rate. Because propeller erosion events do not happen uniformly in either the spatial or time domain, it needs to be corrected in order to find spatial and time averaged erosion rate in order to compare with other processes. Figure 5-108 is a conceptual diagram to show the estimation of the correction coefficients,  $C_s$ , for spatial average.

There are several assumption required to estimate the spatial correction coefficient,  $C_s$ , caused by the spatial non-uniformity of propeller erosion. These assumptions are given in Figure 5-108 and the first one: the erosion area caused by a vessel at a time equals  $W_v^2$ , where  $W_v$  is the width of the vessel that causes the erosion, is probably a rather arbitrary selected number. More studies are needed to have a better and accurate number on this issue.

For correcting the non-uniformity in time domain, we also have several assumptions that are given in Figure 5-109. The assumption of a 5 knots vessel speed may be on the high end. Actually the time required to dock a vessel while tugboats (if used) are still running shall also be considered. A better estimation on the vessel speed, however, requires experience from vessel operation, and can be obtained later.

The percentage of quay use can be obtained from the port authority. Usually this information is available for a long time, and an averaged value should be used. The assumptions given in Figure 5-108 and Figure 5-109 should also be adjusted to reflect a different local condition.

The above two correction coefficients can be estimated relatively easily. Assuming that the small basin in the San Diego Bay can be represented by a 300 m x 100 m rectangular basin, 10 quays were designed for this particular basin with an average quay length of 70 m. The spatial correction coefficient  $C_s$  can be calculated as  $0.018 \cdot 10 \cdot (70)^2 / (300 \times 100) = 0.03$ . The time domain correction coefficient with a 5 knot vessel speed and 50% use rate for quays, would give  $C_t = 0.0006$ . If the vessel speed is 2 knots, then  $C_t$  would increase to  $= 0.0015$ .

For a propeller wash, a rather large excess bed shear stress,  $\tau_{ex}$ , should be used, *e.g.*,  $\tau_{ex} = 0.3$  Pa. The experimental results using the VIMS Sea Carousel can provide this information by extrapolation, *e.g.*,  $0.01 \text{ g/cm}^2/\text{s}$  in the Pearl Harbor and  $0.015 \text{ g/cm}^2/\text{s}$  in the San Diego Bay. The selection of above specified  $\tau_{ex}$  may be subjective, but it represent a rarely occurring event and thus require a large  $\tau_{ex}$ . The effective erosion rate at the San Diego sites would be  $0.0006 \cdot 0.03 \cdot 0.015 \text{ g/cm}^2/\text{s} = 2.7 \times 10^{-7} \text{ g/cm}^2/\text{s}$ .

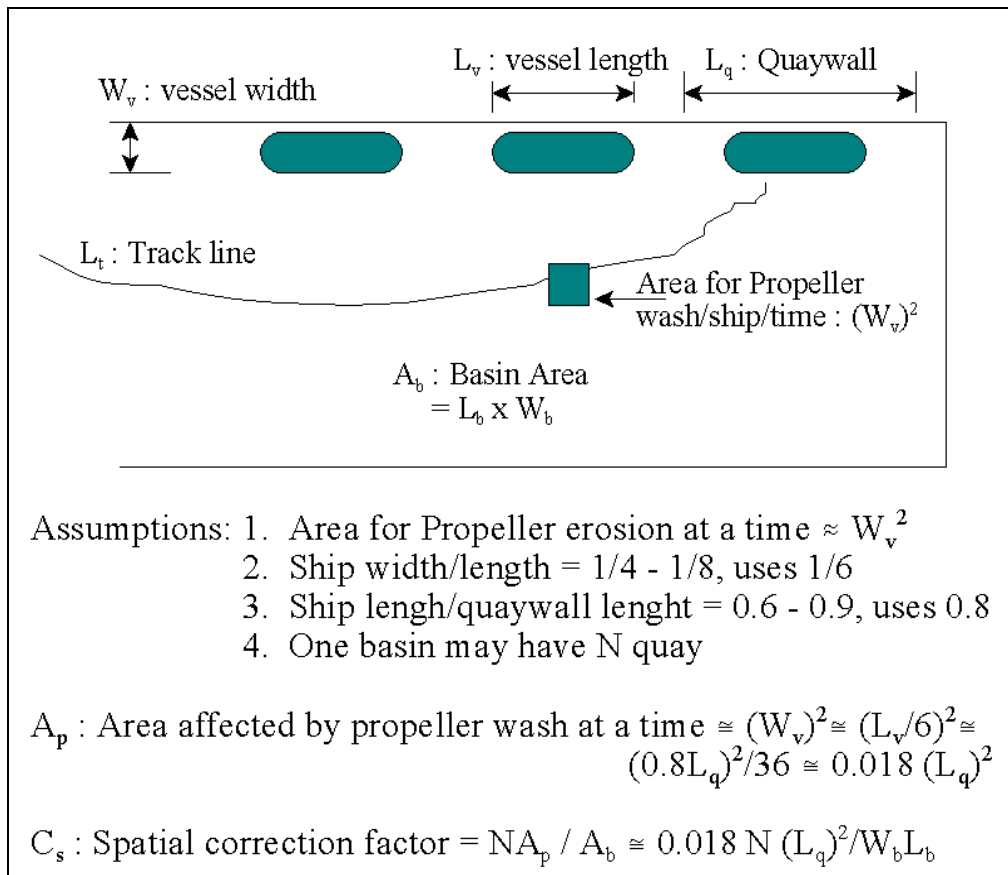
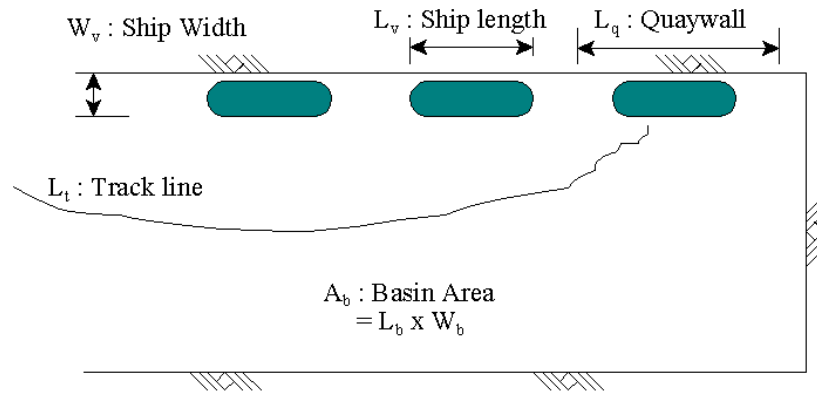


Figure 5-108. Correction coefficient for spatially averaged erosion rate  $C_s$  for at basin subject to non-uniform propeller wash events.





- Assumptions:
1. The percentage of quay uses  $\approx p_s$
  2. Each use may take  $M$  days
  3. Only one move-in and move-out for one use
  4. Vessel speed ( $U_s$ ) about 5 knots
  5. All propeller erosions are independent events

$N_t$  : Total numbers that propeller erosion may occur

$$\approx 2 * 365 \text{ days} * P_s / M * N$$

$T_t$  : Averaged time for a propeller erosion at a place  $\approx W_v / U_s \approx 0.053 L_q$   
with  $L_q$  in meter and  $T_t$  in second (e.g.,  $T_t = 10.6 \text{ s}$  for  $L_q = 200 \text{ m}$ ).

$C_t$  : Time correction factor  $= T_t N_t / (365 * 86400)$

Figure 5-109. Correction coefficient for the time averaged effect on erosion rate.

## 5.7 LABORATORY SEDIMENT FLUME MEASUREMENTS

### Methods

Core samples for flume analysis were collected from each site using the Multicore sampling device. Cores were stored on ice until the flume analysis was done. Cores were loaded into the flume using an adaptor for core tubes used with the Multicore device (Figure 5-110). The cores were placed on a piston that is controlled by an electronic stepper motor to raise and lower the sediment column within the core tube. The sediment surface should be manually raised to be flush with the bottom of the flume channel. The height of the core is maintained by a laser guidance system during each flume run. Analyses were done to determine the critical shear stress of surface sediments at both sites. Detailed methods are given below.

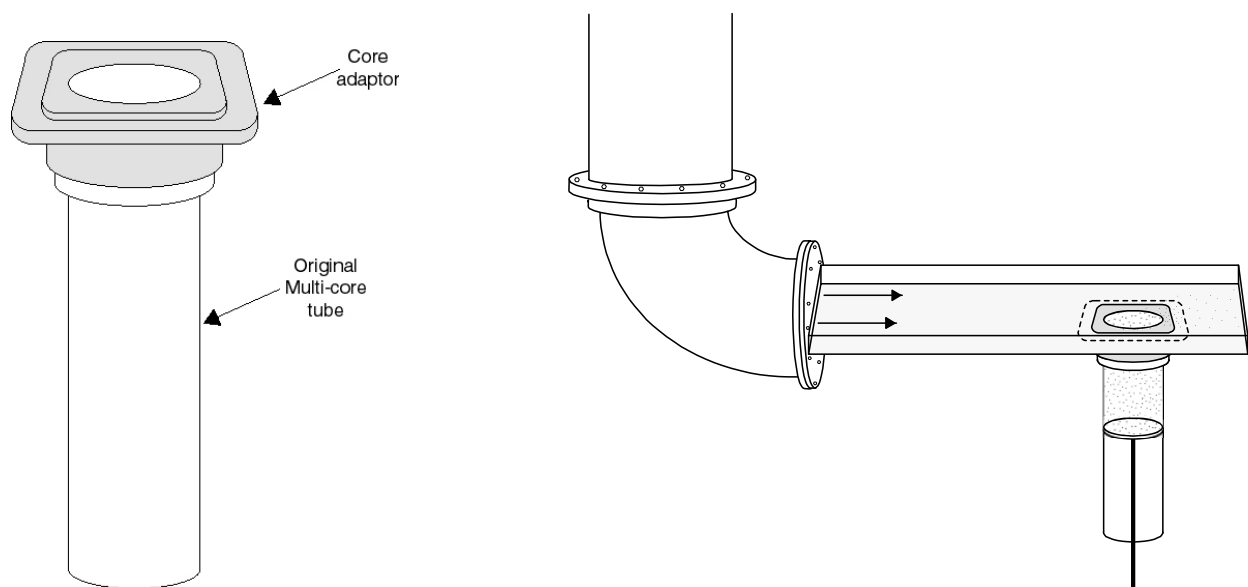


Figure 5-110. This figure illustrates the core adapter (in gray) used to run sediment analyses in the SSC sediment flume.

### Critical Shear Stress

Shear stress is produced at the bed as a result of friction between the flowing water and the solid bottom boundary. At a certain flow velocity, the combined drag and lift forces on the uppermost particles of the sediment bed are great enough to dislodge them from their resting positions. This velocity is related to the critical shear stress for erosion, which is defined as the shear stress at which a small, but accurately measurable rate of erosion occurs. For this application, the critical shear stress has been defined as the shear stress that causes an erosion rate of  $10^{-4} \text{ cm} \cdot \text{s}^{-1}$ .

The critical shear stress for each core was determined by slowly increasing the flow rate of water over the surface of the core. The initial flow rate for the experiment was  $5 \text{ cm}\cdot\text{s}^{-1}$ , with no sediment movement occurring. The flow rate was incremented by approximately  $1 \text{ cm}\cdot\text{s}^{-1}$  during each step until regular sediment movement commenced (Figure 5-111). The erosion rate at each shear stress (step) was calculated by taking the total amount of erosion during each step over the elapsed time of the step. The critical shear stress can be determined by plotting shear stress against the erosion rate and performing a power law fit to the line:  $y = Ax^B$ . The critical shear stress,  $\tau_c$  in dynes/cm<sup>2</sup>, can be then can be calculated using this best-fit equation:  $\tau_c = (0.0001/A)^{1/B}$ .

## Results

Results of the critical shear stress analyses are show in Figure 5-112. Surface sediments at Bishop Point required ~3 times the shear stress as sediments at Southeast Loch for sediment erosion to initiate. This compares well with observations of sediment type at each site, where sediments at Bishop Point were observed to consist mainly of coarse sands and sediment at Southeast Loch were much softer, silty sediments that were visibly bioturbated. Table 5-28 shows values of critical shear stress, as determined by the SSC Sediment Flume and the VIMS In-situ Flume at both sites. Values for critical shear stress show the same trend, however actual values are somewhat different. This may be a result of artifacts presented by each one of the methods, or by the functional definition of critical shear stress used by the user.

	SSC Sediment Flume (dynes/cm <sup>2</sup> )	VIMS In-situ Flume (dynes/cm <sup>2</sup> )
Southeast Loch	1.3	0.7
Bishop Point	4.5	1.3

Table 5-28. Values of critical shear stress, as measured by the SSC Sediment Flume and the VIMS In-situ Flume.

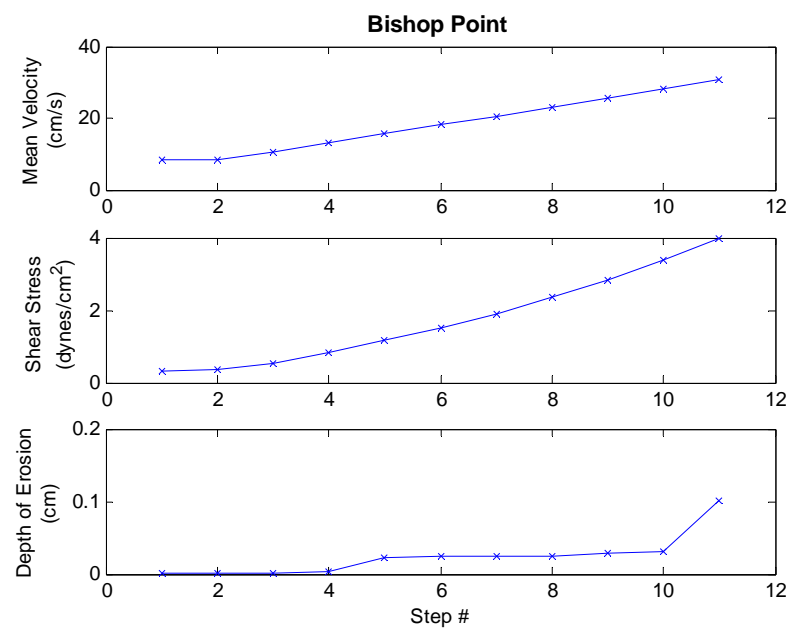
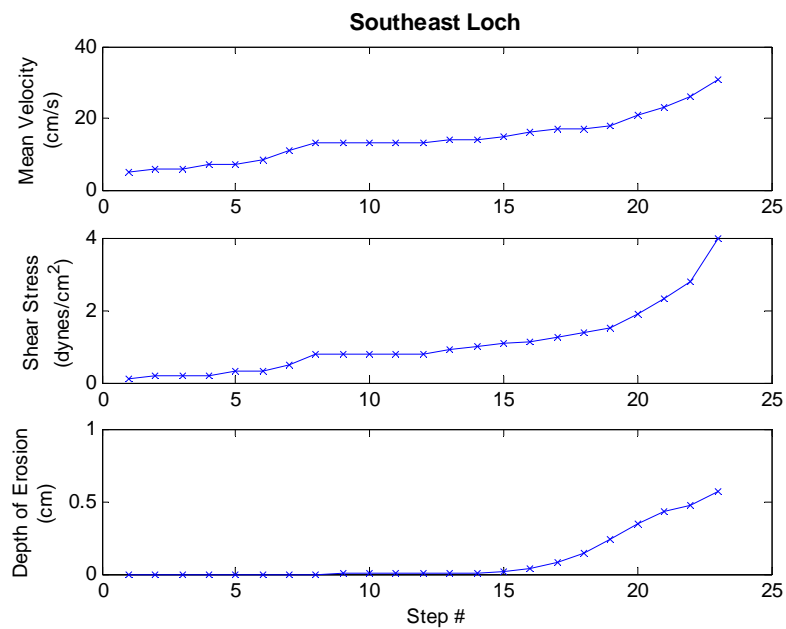


Figure 5-111. A critical shear stress analysis was done at each site. To perform this analysis, the surface of the sediment core was subjected to an increasing amount of shear stress until sediment movement commence.

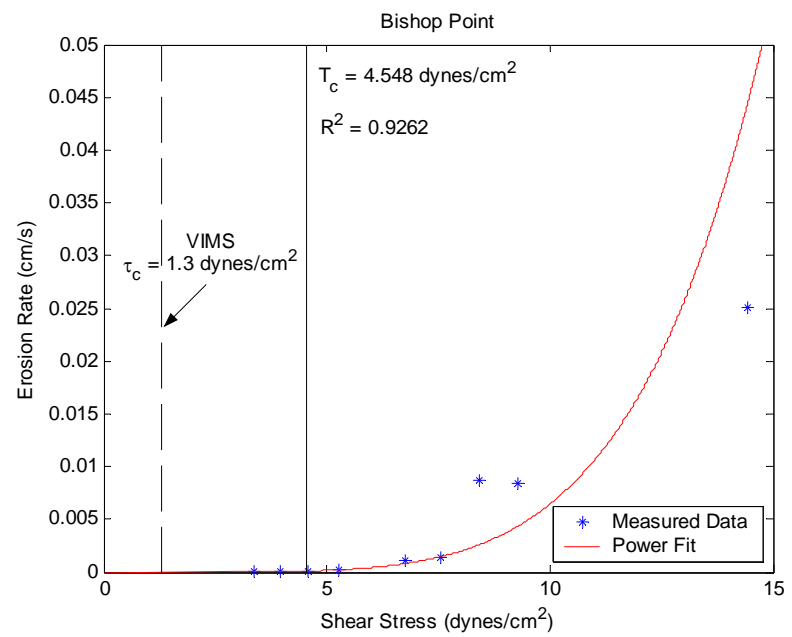
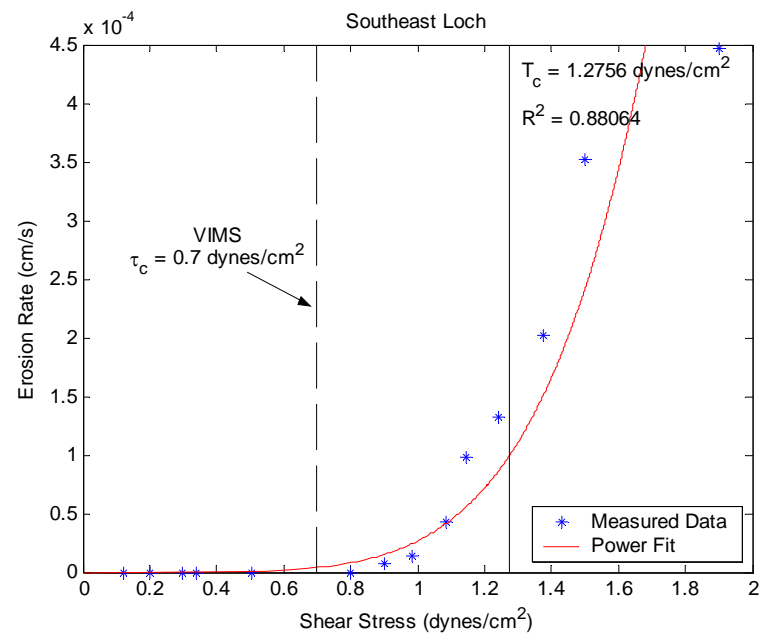


Figure 5-112. Results of the critical shear stress analysis show that sediments at Bishop Point require a much higher shear stress (~3x) than sediments at Southeast Loch before sediment erosion will occur. The  $R^2$  values show that the fit was very good for both regressions.

## 5.8 BOTTOM CURRENTS AND SHEAR STRESS

### Introduction

As a contaminant transport pathway, erosion of the sediment bed depends on both the properties of the bed, and the energy of the overlying water. In order to evaluate erosion as a potential pathway for contaminant mobility within the PRISM framework, current meters were deployed at the Bishop Point-C (BPC) and Southeast Loch-C (SLC) sites in Pearl Harbor. Currents were measured near the bed to provide estimates of the bottom stresses that occur at the site during typical conditions. These measurements, when combined with the in-situ and laboratory flume studies, provide a means of evaluating whether or not erosion would occur and then quantifying the volume of sediments that could be transported from the site by this process.

### Methods

S4 electromagnetic current meters were deployed at the SLC site from 12/14/2002 to 1/07/2003 and at the BPC site from 12/16/2002 to 1/07/2003. The deployment period encompassed a two-week spring-neap tide cycle. Deployment locations are shown in Figure 5-113.

The S4 is a 25 cm diameter spherical instrument designed to measure the magnitude and direction of horizontal current motion in a water environment. The S4 measures the voltage resulting from the motion of a conductor (water flow velocity) through a magnetic field according to Faraday's law of electromagnetic induction. Faraday's law defines the voltage produced in a conductor as the product of the speed of the conductor (water flow velocity) times the magnitude of the magnetic field times the length of the conductor. In the case of the S4, the conductor length is the effective path between the sensing electrodes. The magnetic field intensity is generated by a circular coil, internal to the S4, driven by a precisely regulated alternating current. The use of an alternating magnetic field and synchronous detection techniques to measure the voltage at the sensing electrodes provides an extremely stable, low noise current measurement. Two orthogonal pairs of electrodes and an internal flux gate compass provide the current vector. Because of its low threshold and low noise level, the S4 is the current meter of choice for low current regimes such as those encountered in the protected Pearl Harbor region. The S4s are configured for a current speed range of 0-50 with an accuracy of about  $\pm 1$  cm/sec. The directional component from the flux-gate compass has a resolution of 0.5 degrees and an accuracy of about  $\pm 2$  deg.

For these deployments, the current meters were deployed just above the bottom as shown in Figure 5-114. This was done using divers by first driving an aluminum stake into the sediment, and then bolting the current meter to the stake. The current meters were programmed to collect a 2 min sample average at 2 hz every 4 min.

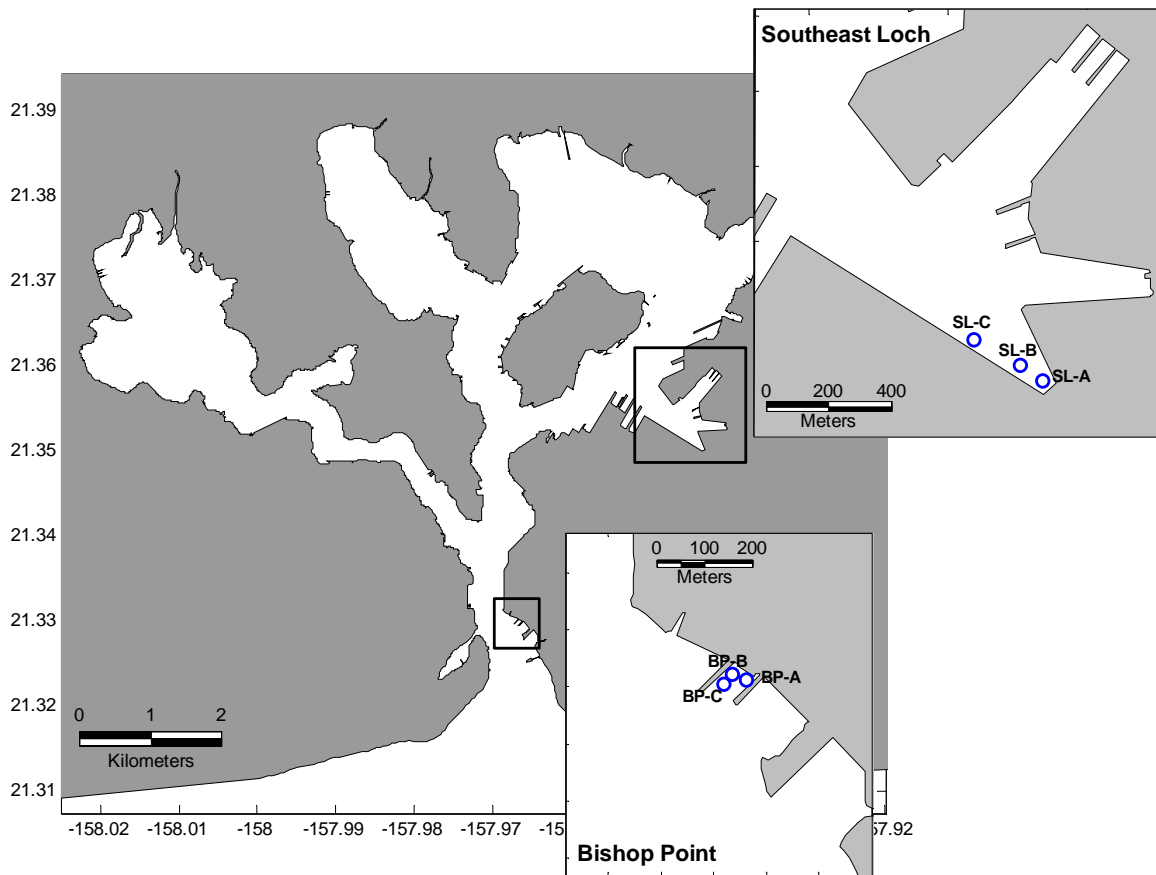


Figure 5-113. Deployment locations for current meters at the BPC (Bishop Point) and SLC (Southeast Loch) stations.

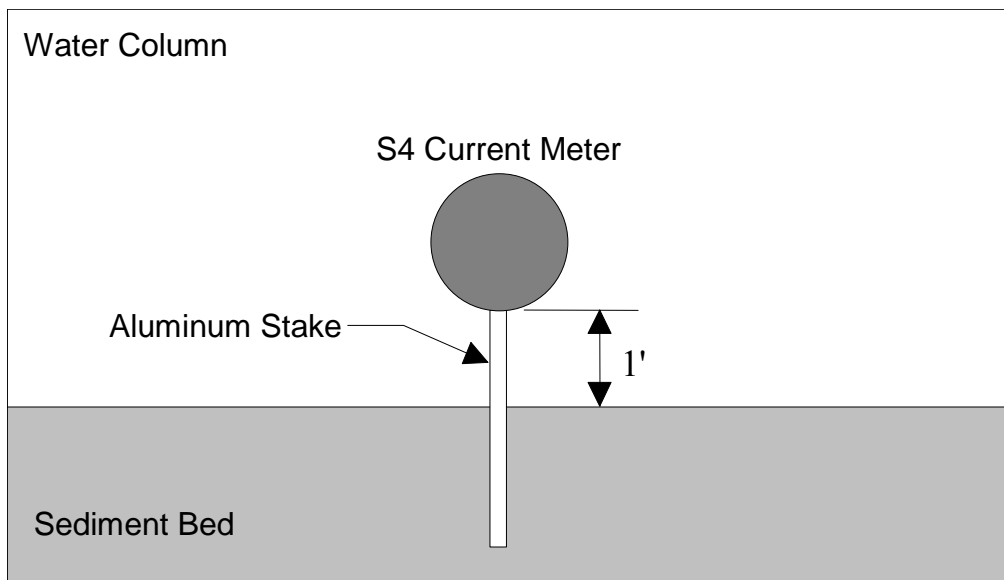


Figure 5-114. Current meter locations and deployment configuration.

## Results and Discussion

Results from the current meter deployments are shown in Figure 5-115 - Figure 5-116. In general, we observed very low current speeds at SLC (0-1.5 cm/s), and somewhat higher current speeds at BPC (0-10 cm/s). Currents at the BPC site consistently aligned toward the southwest (Figure 5-117) and currents at the SLC site were predominantly aligned toward the north (Figure 5-118).

The measured currents were used to calculate estimated bottom shear stresses for the deployment periods. This was carried out following the method described by Dyer (1985) such that

$$\tau_o = \rho C_D U^2$$

where  $\tau_o$  is the bed shear stress,  $\rho$  is the fluid density,  $C_D$  is a drag coefficient, and  $U$  is the current speed. In this case, the current meters were deployed ~43 cm above the bed so we take

$$\tau_o = \rho C_{43} U_{43}^2$$

where  $U_{43}$  is the current measured at 43 cm above the bed, and  $C_{43}$  is the corresponding drag coefficient calculated as

$$C_{43} = \frac{\kappa}{\ln(43/z_o)}$$

where  $\kappa$  is the Von Karmen constant (0.4), and  $z_o$  is the roughness length, taken to be 0.002 for silty sand (Dyer, 1985).

The estimated bottom shear stresses are shown in Figure 5-119. As expected, the shear stresses at SLC are generally very low ( $\sim 0.04$  dyn/cm<sup>2</sup>). Shear stresses at BPC were somewhat higher, ranging from about 0.1-0.5 dyn/cm<sup>2</sup>. The estimated shear stresses were compared to the critical shear stress measured at the sites using both an in-situ annular flume and a laboratory SedFlume (0.17 Pa = 1.7 dyn/cm<sup>2</sup>). Results indicate that the critical shear stress is never exceeded at either site.



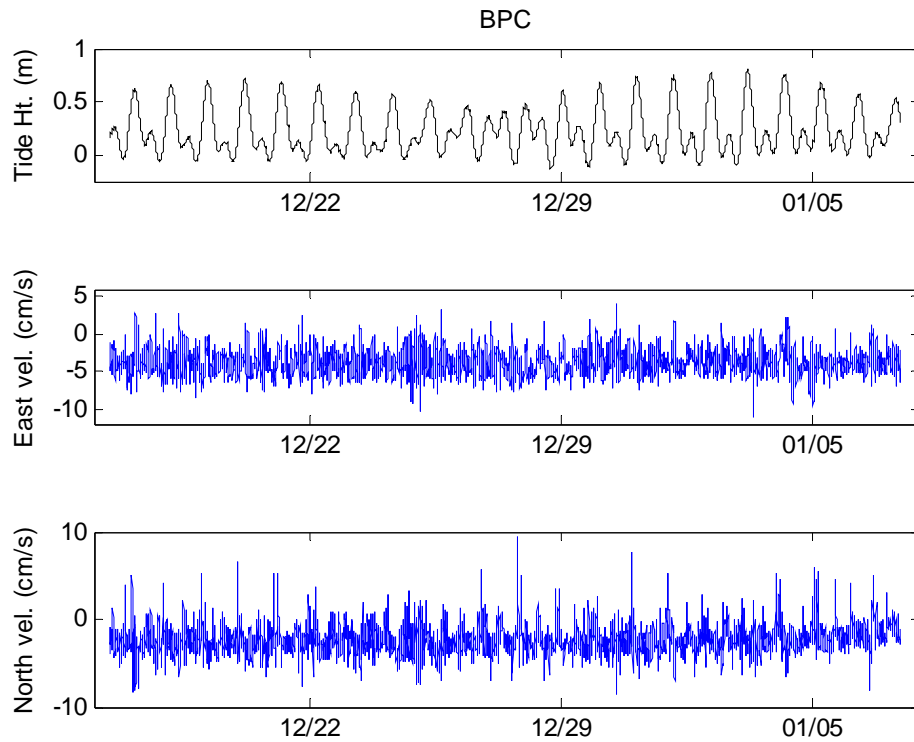


Figure 5-115. Bishop Creek tide and currents

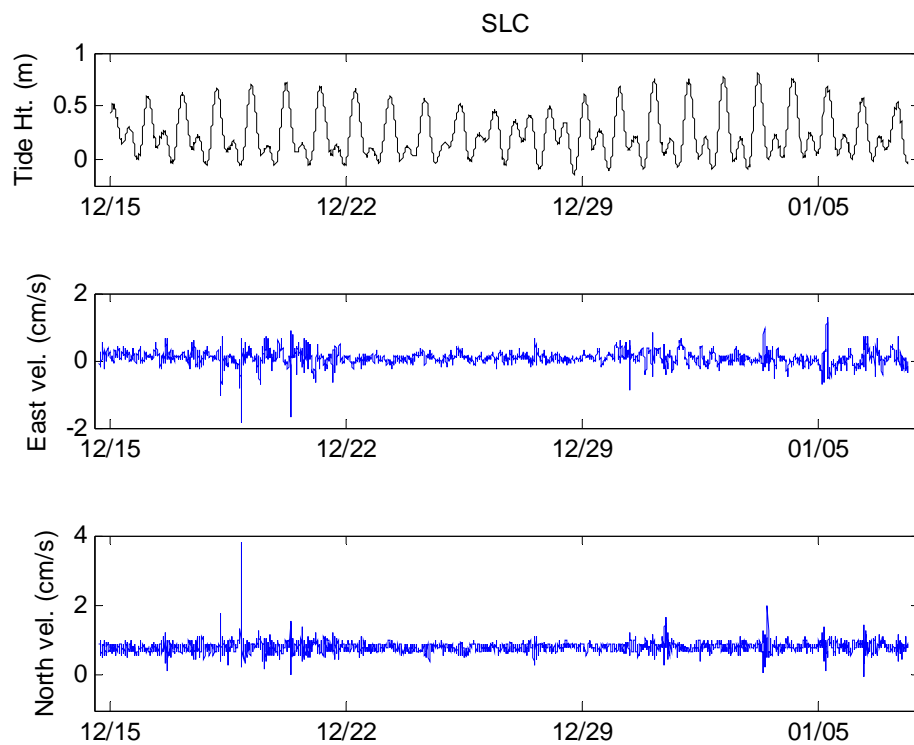


Figure 5-116. Southeast Loch tide and currents

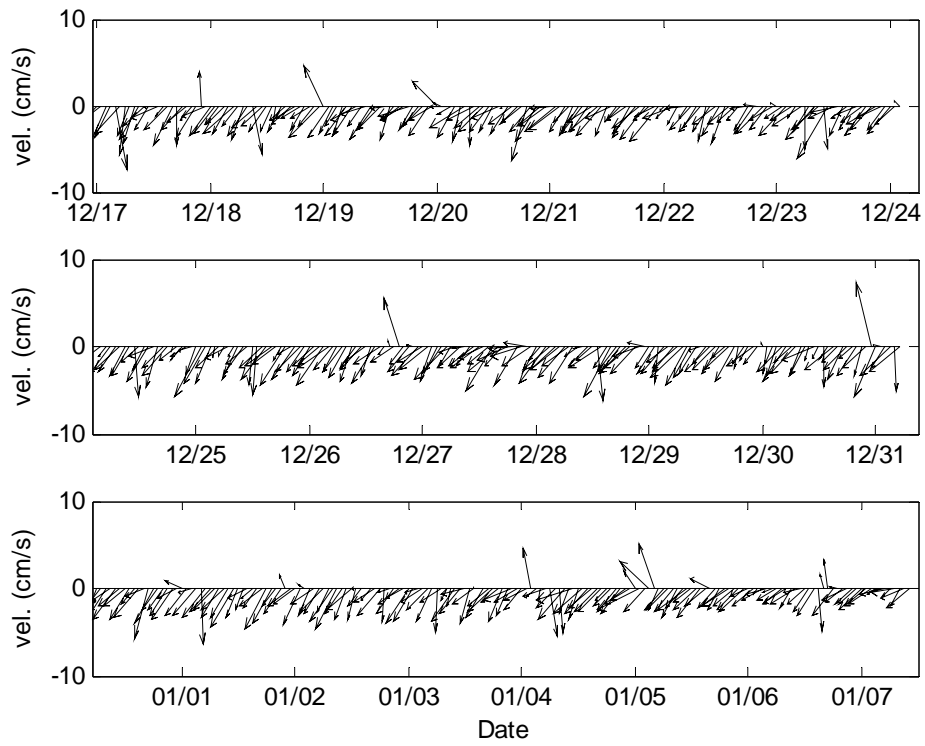


Figure 5-117. BPC near-bottom currents.

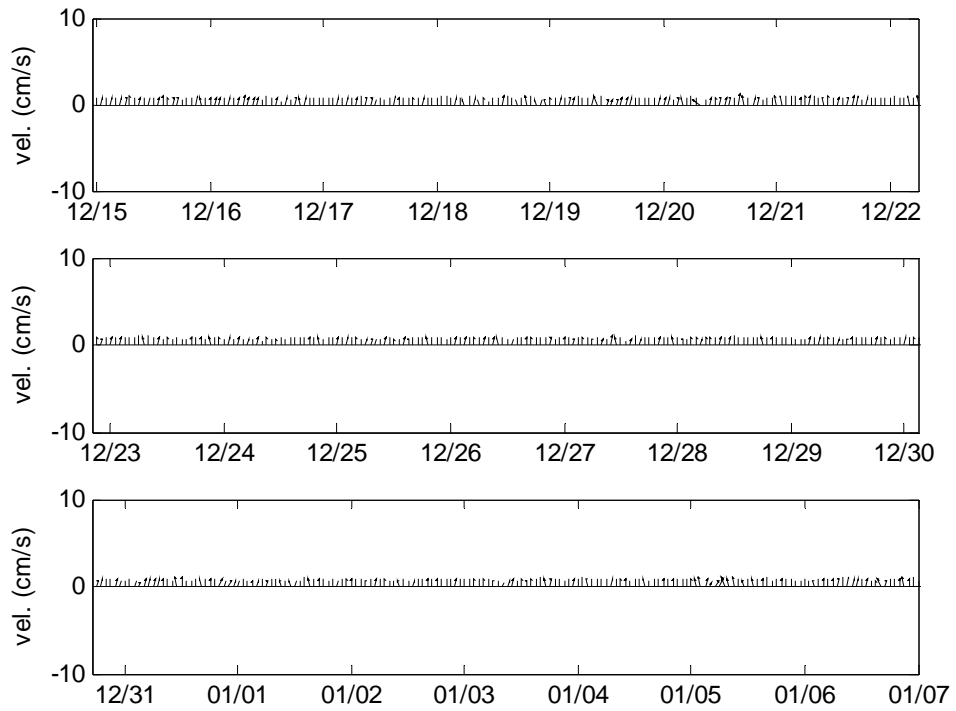


Figure 5-118. SLC near-bottom currents.

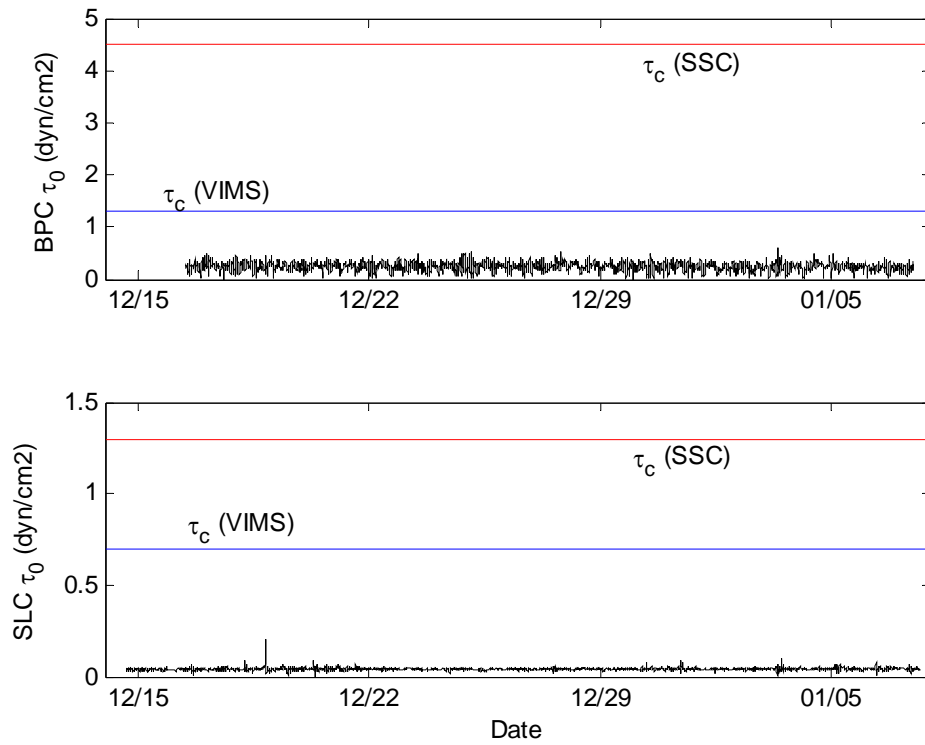


Figure 5-119. Estimated bottom shear stress vs. critical shear stress from the VIMS in-situ annular flume and SSC SedFlume.

## 5.9 GEOCHEMISTRY OF PORE WATERS AND SEDIMENTS

### Introduction

The major purpose of the present program Pathway Ranking for In-place Sediment Management (PRISM) in Pearl Harbor is the assessment of the various physical, chemical, and biological processes affecting these sediments and their biota. Under the auspices of PRISM, our laboratory has undertaken the study of the chemistry of the interstitial fluids and associated sediments in a number of cores centered around the Bishop Point and Southeast Loch areas of Pearl Harbor. The study concentrated on three cores from Merry Point in the Southeast Loch and three cores from Bishop Point. The locations of the sampling sites are presented in Figure 5-120.

### Methods

#### Pore fluids

Pore waters were extracted from the sediments immediately after the sediment retrieval by means of centrifugation (Sorval, 10K x g) under nitrogen to prevent oxidation of labile components, e.g.,  $\text{Fe}^{2+}$  and  $\text{HS}^-$ . Alkalinity was determined by acidimetric titration, whereas ammonium, sulfide, sulfate, and phosphate were determined by spectro-photometry (Gieskes, Gamo, and Brumsack, 1991). Major elements and trace metals were determined by analysis using an ICP-OES. Dissolved copper was determined in special acid preserved samples and analyses were carried out by means of ICP-MS Spectroscopy. In our methodology we used pore waters ten times diluted with especially clean distilled water. Standards were made with seawater that had been stripped of trace metals, but had a matrix similar to that of the pore fluids. Typical accuracies are  $\pm 10\%$  or at lower levels  $\pm 2\text{ nM}$ . Data are presented in Table 5-29.

#### Micro-electrode Measurements

The vertical oxygen distribution was measured at in situ temperatures in intact cores using Clark-type microelectrodes (Unisense, Denmark) that were equipped with a built-in reference and guard electrode (Revsbech and Jørgensen, 1986; Revsbech, 1989). The sensors had a tip diameter of 15-20  $\mu\text{m}$ , a stirring sensitivity of  $< 2\%$ , and a response time of  $< 1\text{ sec}$ . The electrode currents were linearly responsive between 0-100% air saturation of oxygen and were calibrated at in situ temperatures in nitrogen-purged seawater and

100% saturated seawater (salinity = 36). Oxygen profiling was performed in the dark and after exposure to ambient laboratory light for 5, 10 and 15 minutes. Sulfide micro-gradients were measured using a miniaturized amperometric  $\text{H}_2\text{S}$  sensor with an internal reference and guard anode (Jeroschewsky, Steuckart, and Kuehl, 1996). The sensors had a 5-cm long, tapered tip

with a tip diameter of 30 – 50  $\mu\text{m}$ . Calibration was performed after the sensor signal had stabilized during pre-polarization of 24 hours. A stock solution of  $\text{S}^{2-}$  (i. e., 100 mM) was prepared from dissolving  $\text{Na}_2\text{S}$  in  $\text{N}_2$ -flushed 0.1 M NaOH in a closed container. The final concentration of stock solution was determined by standard analysis (Cline, 1969). Calibration points were prepared by injecting suitable amounts of the  $\text{S}^{2-}$  stock solution into calibration vials containing an oxygen free buffer solution (100 mM phosphate buffer, pH 7). The electrodes were attached to a motor-controlled micromanipulator that was mounted on a heavy stand. Oxygen concentrations were measured at depth intervals of typically 200  $\mu\text{m}$  and sulfide concentrations were measured in 500-  $\mu\text{m}$  depth intervals. The position of the micro-sensors was observed using a dissecting microscope while the signals were amplified and transformed to mV by a Unisense PA 2000 picoammeter and directly recorded on a computer.

### **Solids analysis**

Solid phases were submitted to the digestion of dried (80 °C for 24 hours) solids via a bead formation by fusion with a lithium borate/tetra-borate flux and subsequent dissolution in 5 % nitric acid. Analyses were carried out by means of ICP-OES Spectroscopy. The data are presented in Table 5-30 and Table 5-31.

## **Results**

### **Pore fluids**

In order to discuss the distribution of redox sensitive species it is appropriate to summarize the usually observed sequence in oxidation/reduction reactions associated with the decomposition (oxidation) of organic matter in marine sediments. The so-called redox sequence is presented in Figure 5-121. As the generation of dissolved manganese and iron occurs in the very close vicinity of the sediment-water interface, no nitrate will be expected in the near surface zone. In addition, as will be demonstrated below, dissolved oxygen penetration in most of the cores of this study, does not generally extend to deeper than a few centimeters, unless bioirrigation is of importance. Sulfate reduction processes usually only become of importance when the processes of manganese oxide and iron oxide reduction are not of importance any more in the process of organic carbon diagenesis in the sediments. These processes of oxidation of organic matter are accompanied by the production of ammonium and dissolved phosphate.

#### *South East Loch Merry Point*

The location of the stations is given in Figure 5-120. Note that Station A is the closest to the edge of the Harbor at this location. Concentration depth profiles of alkalinity, sulfate, and ammonium (Figure 5-122) show strong similarities, with rapid changes occurring below ~ 8 cm depth. Distinct sulfide increases are observed only in Cores A and C, whereas no significant sulfide was detected in Core B. The data for dissolved manganese and iron indicate mobilization of these elements in the upper 2-4 cm of the sediments, with large increases in Mn and Fe occurring only in Core C. Manganese profiles indicate that dissolution of manganese oxides occurs at or immediately below the sediment-water interface. Decreases with depth in manganese and iron below their maxima are the result of manganese carbonate formation (elevated alkalinities) and iron sulfide precipitation. Below the zone of iron oxide reduction, the sulfate reduction zone is initiated, typically leading to the large increases in ammonium and phosphate as a result of

release by the oxidizing organic matter. Sulfide increases are relatively small compared with the sulfate decreases, presumably as a result of the above inferred iron sulfide precipitation reactions. Dissolved silica shows rapid increases in the upper 2 cm, followed by a minimum at ~ 4-6 cm.

The major constituents K and Mg show almost constancy with depth. Minor decreases are essentially within the accuracy of the data (~ 2-3%). On the other hand, dissolved calcium shows a slight maximum at ~3-4 cm, followed by a distinct decrease with depth. Whereas the shallow calcium maximum may be associated with carbonate dissolution, the subsequent decrease at increasing depths is due to the precipitation of calcium carbonate.

Sulfide appears at shallow depths, usually just below the zone of manganese and iron oxide dissolution. If bio-turbation or bio-irrigation is of importance in these cores, these phenomena will mostly be restricted to the upper ~ 6-8 cm of the cores. Below these depths concentration depth gradients in sulfate and sulfide are quite pronounced, arguing against the occurrence of such perturbation processes below ~ 8 cm depth.

Microprofiles of oxygen (Figure 5-123) indicate that the presence of dissolved oxygen is normally restricted to ~ 2 mm in cores from Stations A and B, and even less (~ 1mm) in the core from Station C. No detectable effect to light exposure on oxygen concentrations was observed in these cores. Many “pock marks” in the sediments have been observed by scuba divers in this area of South East Loch. Such phenomena are potentially associated with burrowing activity. However, no large macro-faunal or bio-irrigation activity was observed in the cores that were retrieved from the 3 stations. The sulfide profiles that were measured in cores A and C (Figure 5-123) are in good agreement with the profiles gained from other pore water analyses of the sediment cores. Very low or no sulfide can be detected in the upper 4 cm, but below this layer sulfide concentrations increase with sediment depth to a concentration of 300  $\mu\text{M}$  at 10 cm sediment depth. In contrast, the sulfide profile measured in core B (Figure 5-123) exhibited much lower concentrations (note the different scale of the graph) with maximum values around 20  $\mu\text{M}$  at ~ 3 cm depth below the sediment surface. These very low values are in accordance with the pore water chemical analyses, where sulfide could not be detected in core B. The sulfides probably are associated with a local micro-niche of organic matter degradation.

#### *Bishop Point*

Concentration depth profiles of nutrients and major ions (Figure 5-124) show some similarities to those of South Loch Merry point, but the changes are much less pronounced. Sediments were much harder to penetrate in this case, but the observation of *Callianassa* in Core C is consistent with bio-irrigation processes. Core C has the most pronounced maxima in iron and manganese.

Concentration depth gradients of Ca, Mg, and K are similar in nature to those observed in the South Loch area of Merry Point, albeit with some larger scatter.

Micro-profiles of dissolved oxygen (Figure 5-125) indicate a rapid disappearance of dissolved oxygen at ~ 1 mm sediment depth in the core from station B (Figure 5-125). Exposure to light for a time period of 15 minutes had only a small effect on oxygen production at the interface. The sediment surface of the core from station A was characterized by a high abundance of small

benthic organisms (polychaete tubes and small crustaceans could be observed). Oxygen penetrated up to 3 mm deep into the sediment and the three oxygen profiles exhibited some differences due to the irrigation of the upper millimeters of sediment (Figure 5-125). Exposure to light had a greater effect in this core with an increase of oxygen of 60  $\mu\text{M}$  at the sediment surface (Figure 5-125). Sulfide could not be detected in core A while the profile measured in core BP-B showed a maximum in sulfide concentration ( $\sim 100 \mu\text{M}$ ) between 2 and 5 cm sediment depth. The large scatter of sulfide concentrations indicates distinct local variability. The sulfide measurements in this core agreed with the pore water analyses that showed the initiation of the sulfate decrease below  $\sim 5$  cm depth. This indicates the local variability in the distributions of sulfate and associated increases in sulfide. The core that was retrieved from station C (BP-C) was bioturbated by the burrowing shrimp *Callinassa spec.* The burrows and the burrowing activity of the shrimp could be observed through the clear acrylic walls of the core liner. The burrows continued from the surface through the whole sediment column (20 cm) and had a diameter of  $\sim 7$  mm. The decapod shrimp causes ventilation through their burrows by regular beating with their pleopods. Figure 5-126 shows the disappearance of oxygen within the upper 2.5 mm and a local increase between 28 and 36 mm sediment depth, where the electrode penetrated through a burrow. Figure 5-126 indicates that the oxygen concentration in the burrow is kept at a value of  $\sim 25 \mu\text{M}$ . Due to this strong bio-irrigation activity the oxygen is brought to deeper sediment depth and sulfide was not detected.

#### *Dissolved copper profiles*

Of interest are the depth distributions of dissolved copper in the cores of South East Loch and Bishop Point. The data are presented in Figure 5-127. Note the concentrations of copper in the overlying waters indicated by the arrows (Ernie Arias, personal communication). In general the Cu concentrations are on average  $10 \text{ nM} \pm 5 \text{ nM}$  in the Merry Point cores and  $7 \text{ nM} \pm 3 \text{ nM}$  in the Bishop Point cores. Only in some cases are concentrations higher than observed in the overlying waters, usually at or near the sediment water interface.

#### **Solid Phases**

Both major constituents (Table 5-30) and trace metals (Table 5-31) were determined in the oven dried ( $> 80^\circ\text{C}/24$  hours) solids of all cores.

#### *Major constituents*

Data for the bulk solid major constituents are presented in Figure 5-128. In this study we report calcium concentrations as % CaO in Table 5-30. In the figures, however, we report these data in terms of  $\text{CaCO}_3$ , assuming that all calcium is in the form of calcium carbonate, an assumption that is probably not correct, as some calcium will no doubt reside in an alumino-silicate phase.  $\text{K}_2\text{O}$  concentrations are low and will not be further discussed.

A correlation diagram between  $\text{Al}_2\text{O}_3$  and the other elements (as oxide or carbonate) is presented in Figure 5-129. Generally the trends are roughly linearly correlated, with the exception of  $\text{MgO}$ , where there appear different trends in the Merry Point and Bishop Point areas. At this time the reasons for the different behavior of  $\text{MgO}$  are not clear and outside the scope of this work.

The molar ratio of titanium over aluminum (Ti/Al) is shown in Figure 5-130. Whereas the Ti/Al ratio in the Merry Point cores is  $0.095 \pm 0.005$ , this ratio is different in all three Bishop Point cores. Whether these differences are due to small changes in the clays or some systematic error is difficult to determine. Nonetheless, the data clearly show that the clay fraction is typically high in the Ti content, which is due to the volcanic origins of the clays.

#### *Trace metals*

The contents of Cr, Mn, Ni, Cu, and Zn (Table 5-31) are presented as functions of depth in Figure 5-131. Concentrations of trace metals in the Merry Point cores are higher than those in the Bishop Point cores. This is mostly because of the greater dilution of the Bishop Point sediments by coral derived carbonate.

Chadwick et al. (1999) suggest that plots of the Fe concentrations versus those of the trace metals may be instructive to determine potential excess values of the trace metals over those of presumed background values. Of importance in this analysis are the ERL (Effect Low Range – less than 10 % of compiled biological studies indicate adverse effects) and ERM (Effect Medium Range – more than 50% show adverse effects) values. Figure 5-132 combines the plots of Fe vs. the trace metals. Whereas the data for Cr and Mn show almost linear dependencies, the plots of Fe vs. Ni, Cu, and Zn show considerable scatter. This can best be understood in terms of the contaminant nature of these elements in Pearl Harbor sediments.

For the elements Ni, Cu, and Zn, the data from Merry Point show these elements to be “elements of concern”, but for Bishop Point most of the data indicate values below the ERM, but above the ERL. The pertinent question, of course, is whether the levels of ERL and ERM, determined for San Diego Bay, are also of importance in Pearl Harbor. Much of this depends on the nature of the biota affected by these “definitions”. In other words, what are the relevant levels of ERM and ERL in the case of the sediments in Pearl Harbor.

### **Discussion**

In this section we consider the significance of our observations within the framework of the PRISM Program on “Pathway Ranking for In-Place Sediment Management”. The previous program studied the sediments of the Paleta Creek area of San Diego Bay, whereas the present exercise centered on two areas of the Pearl Harbor.

#### **Pore fluid observations**

The principal aim of the present study was to establish the bio-geo-chemical conditions prevailing in the sediments. Towards this purpose the use of concentration versus depth distributions is of importance.

Pore water profiles were obtained by slicing the sediments, and, therefore, the concentration profiles of the pore water constituents are representative of the “average” pore fluid at the depth horizons of the slices. In the case of a micro-electrode profiles, however, a very small surface area of the cores is profiled with depth. Thus a somewhat greater variability in the pore water



oxygen and sulfide concentrations can be expected, especially when bio-turbation and bio-irrigation are of importance.

In most concentration-depth profiles gradual changes with depth are observed, indicating that on average the data are representative of in situ conditions. Thus the various concentration depth profiles do clearly show the zonation of the dominant redox processes in the sediments. If we assume that the onset of the sulfate reduction zone also represents the depth of the influence of potential bioturbation, then in the Merry Point cores the average influence of bio-irrigation will be less than 6-8 cm, and at Bishop Point less than ~ 6 cm. The micro-profile of sulfide indicates the production of sulfide as shallow as 2 cm (Core BPB-1).

Visual divers' and video observations of the sediments do indeed indicate more intensive (shallow ?) pockmarks at Merry Point than at Bishop Point, where most burrowing activity is in the upper cm or so (Joe Germano, personal communication). Of interest are the variations in the dissolved silica profiles. At both sites minima in silica are observed between 6-10 cm at Merry Point and 2-6 cm at Bishop Point. If these minima are related to the introduction of low silica fluids by means of bio-irrigation, then there appears good evidence for the potential importance of bio-irrigation at both sites. This is also evident from the dissolved oxygen profile in Core BPC-7 (Figure 5-126).

The nature of the concentration depth profiles is such that there is little evidence for important upward water advection in these cores. This is particularly evident from either the Ca or the SO<sub>4</sub> profiles.

In the Merry Point cores it is evident that the generation of dissolved manganese and iron characterize the pore fluids in the upper few centimeters from the sediment-water interface. Below this depth, sulfate reduction processes become of importance. On average, the dissolved copper profiles indicate a rapid decrease in Cu with depth to values well below the overlying seawater concentrations (indicated by arrows) at or immediately below the sediment-water interface. Average concentrations fluctuate around 10 nM  $\pm$  5 at Merry Point and around 7 nM  $\pm$  3 at Bishop Point. Only in rare cases are values higher than those prevailing in the overlying waters, mainly in the top of the cores. This observation implies a potential source of dissolved copper at or very near the sediment-water interface. Thus any benthic fluxes into the water column, determined by benthic flux meters, must be associated with release at or very close to the bottom boundary (most likely from depths well within 0.2 cm of sediment-water interface). Benthic fluxes (Bart Chadwick, personal communication) were measured at 13.6  $\mu$ g/m<sup>2</sup>/day  $\pm$  86 at Bishop Point and 20  $\mu$ g/m<sup>2</sup>/day  $\pm$  22 at Southeast Loch (Bart Chadwick, personal communication). Naturally, especially because there exists a downward trend in the Cu concentrations in the sediments, there must also occur a flux of Cu into (and out of) the sediments from the same source at the sediment water interface. Dissolved manganese shows maxima within the upper 2 centimeters and thus manganese should have a substantial benthic flux as is evident from the shallow generation of dissolved manganese and the steep concentration gradients. Measured fluxes for manganese were respectively 2117  $\mu$ g/m<sup>2</sup>/day  $\pm$  3094 at Bishop Point and 1245  $\mu$ g/m<sup>2</sup>/day  $\pm$  803 at Merry Point (Bart Chadwick, personal communication).

## **Solid Phases**

### *Major constituents*

As demonstrated in Figure 5-128 and Figure 5-129, calcium carbonate is a major component of the sediments, mostly stemming from coral debris. With the exception of MgO concentrations, the correlation of each major constituent ( $\text{CaCO}_3$ ,  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{SiO}_2$ ; Figure 5-128) with  $\text{Al}_2\text{O}_3$  is essentially linear, suggesting that dilution by carbonate is of major importance and that the alumino-silicate fraction is of similar origins. As indicated before, we are unable to assess the significance of the  $\text{Al}_2\text{O}_3$  – MgO correlation.

### *Minor constituents*

The correlation plots between Fe % and the trace metals concentrations are only close to linear for Cr and Mn. For Ni, Cu, and Zn, however, considerable scatter occurs. The data, particularly in Merry Point stations, suggest anthropogenic contributions to the latter elements. The latter three elements also show scattered correlations among themselves, suggesting a variety of sources for these constituents. The Merry Point data suggest levels above the conventional ERM level both for Ni and Cu. The question remains whether the ERM level chosen is relevant for the biota of Pearl Harbor sediments, which is beyond the scope of this report.

## **Conclusions**

The data presented in this report are intended to present the background geochemical data for the two PRISM-2 study areas in Pearl Harbor. Pore water geochemical data indicate that several diagenetic zones characterize the sediments:

1. Dissolved oxygen rapidly diminishes below the sediment-water interface (penetration depths about 2-3 mm). Only in the case of heavy burrowing activity do micro-profiles of oxygen indicate deeper penetrations of minor amounts of oxygen into the burrows. Oxygen will be depleted with distance away from these burrows.
2. The zone of manganese oxide reduction initiates at or immediately below the zone of dissolved oxygen penetration; this is usually characterized by a shallow maximum in dissolved manganese as well as the finite Mn concentration at very shallow depths below the sediment water interface.
3. Dissolved iron shows shallow maxima at or just below the maxima associated with dissolved manganese.
4. Immediately below the zone of manganese and iron oxide reduction, the zone of sulfide production is initiated. This is particularly evident from pore water profiles of dissolved sulfide in the Merry Point cores (c.f., Figure 5-122 and Figure 5-123). We argue that the initiation of the zone of sulfate reduction and sulfide generation is the lower boundary for processes of active bio-turbation and bioirrigation, i.e., at Merry Point the average influence of bio-irrigation will be less than 6-8 cm and at Bishop Point less than ~ 6 cm.

5. Profiles of dissolved copper indicate generally rapid decreases below the sediment- water interface to values much lower than in the overlying waters. This observation signifies the importance of processes at or just below the sediment water interface in causing potential benthic fluxes of copper into or out of the overlying waters.

Major constituents of the sedimentary solids indicate the importance of contributions of a carbonate fraction (coral debris) to the sediments. This inorganic component serves as a dilutant for trace metals in the sediments.

The distributions of minor elements (Cr, Mn, Ni, Cu, Zn) indicate elevated values of Ni, Cu, and Zn as a result of anthropogenic sources (ship related fouling), whereas chromium stems most likely all from an original sediment component. Similarly, manganese is most likely an element that cycles by itself in these sediments, not necessarily affected by anthropogenic inputs. The observations on the correlation between solid iron contents and the trace metal contents clearly show the pollutant nature of the Ni, Cu, and Zn distributions. For the Merry Point sediments in the South-east Loch, both Cu and Ni concentrations are above the ERM level, which, in principle, makes these “elements of concern” with respect to levels of consequence to the biota.

Table 5-29. Pearl harbor pore water chemistry.

Core	depth (cm-bsf)	Ca (mM)	K (mM)	Mg (mM)	SO <sub>4</sub> (mM)	HS <sup>-</sup> (μM)	Fe (μM)	Mn (μM)	Cu (nM)	Alk. (mM)	NH <sub>4</sub> (μM)	H <sub>4</sub> SiO <sub>4</sub> (μM)	HPO <sub>4</sub> (μM)
SLA 4	0.25	10.56	11.82	54.27	29.39	0.0	15.2	28.4	7.7	3.01	47	213	3
	1.5	11.78	10.47	55.20	29.36	0.0	49.9	31.5	3.1	4.45	54	460	2
	2.5	12.44	10.71	56.17	30.29	0.0	31.4	27.6	2.1	4.37	35	453	6
	3.5	11.61	10.38	54.63	29.35	0.0	26.7	28.0	9.4	4.35	56	467	15
	4.5	10.63	10.35	54.05	29.04	10.0	3.5	10.0	2.4	4.00	65	307	19
	6.5	9.94	10.38	54.36	27.72	40.0	0.3	2.7	7.9	4.64	106		18
	8.5	9.56	10.25	54.13	26.58	70.0	0.0	0.8	3.5	5.44	152	337	31
	10.5	9.47	10.30	54.73	25.67	75.0	0.2	0.4	4.1	6.71	230	299	37
	11.5	8.97	10.25	54.48	23.95	120.0	0.0	0.0	2.0	8.11	304	361	33
	13.5	8.14	10.10	54.11	21.63	200.0	0.1	0.0	1.8	11.13	455	418	38
SLB 4	15.5	7.58	9.95	53.82	19.61	480.0		0.0	1.4	12.86	581	420	
	0.75	10.30	10.46	54.74	28.80		23.0	26.4	11.5	4.43	37	280	1
	1.25	10.13	10.32	54.07	28.63		14.2	21.1	6.2	3.68		316	8
	1.75	10.28	10.27	54.09	28.32		7.7	16.9	3.9	4.03		336	10
	2.5	10.55	10.47	55.07	28.78		12.5	13.8	6.4	4.40	36	366	8
	3.5	10.98	10.01	53.86	28.62		33.2	36.5	8.2	4.73	19	389	16
	4.5	11.13	10.24	54.82	28.71		21.4	14.9	9.9	4.63	10	375	21
	10.5	9.03	10.09	53.44	23.83		10.2	8.8	6.0	8.22	244	453	22
	13.5	7.95	10.00	53.60	19.70		1.4	3.3	14.2	11.86	485	486	50
	16.5	7.21	9.54	51.61	17.66		10.1	7.1	14.3	13.45	543	494	27
SLC 2	19.5	7.10	9.77	52.57	16.98		13.2	8.6	13.2	14.99	634	503	32
	0.25	10.38	10.52	55.26	29.94	0.0	12.9	44.5	8.7	2.78	0	149	0
	0.75	10.38	10.37	54.79	29.56	0.0	38.8	54.0	5.5	2.98	0	223	0
	1.25	10.91	10.69	56.44	30.40	0.0	47.1	53.1	11.3	3.32	5	283	0
	1.75	10.95	10.48	55.76	29.98	0.0	74.2	55.6	10.2	3.49	58	353	1
	2.5	11.37	10.85	55.32	29.64	0.0	192.6	59.7	10.6	4.05	31	369	3
	3.5	12.06	10.37	55.39	29.61	0.0	215.4	62.0	10.7		52	430	1
	3.5	11.96	10.32	54.94	29.82	0.0	227.0	63.1		4.22	52	421	1
	4.5	12.28	10.05	53.66	29.48	0.0	236.7	56.9	14.9	4.13	22	450	2
	6.5	11.04	10.37	54.33	29.36	0.0	32.7	24.0	21.6	3.51	16	226	3
BPA 1	8.5	10.15	10.44	55.06	28.75	0.0	8.5	17.6	13.3	3.96	56	255	8
	10.5	9.35	10.12	53.65	27.32	0.0	1.6	6.2	16.6	4.70	128	278	16
	12.5	8.93	10.26	54.24	25.29	110.0	0.2	2.9	10.4	7.06	280	398	29
	14.5	8.44	10.11	54.11	23.36	615.0	0.2	0.6		9.04	376	437	35
	17.5	7.72	10.03	53.76	20.88	1180.0	0.0	0.0	9.1	11.17	475	492	38
	20.5	6.93	9.82	52.44	18.29	1200.0	0.1	0.0	9.7	13.13	561	513	40
	0.25	9.94	10.08	53.79			2.2	5.2	14.1	2.87	48	78	1
	0.75	9.57	9.62	52.04	28.09		3.9	0.6	9.6	2.99	31	124	1
	1.25	9.35	9.51	51.13	27.64		0.4	0.0	12.2	3.00	25	154	3
	1.75	9.61	9.79	52.54	28.36			0.0	8.2	3.00	35	160	3
BPB 1	2.5	9.63	10.00	53.20	29.04		0.0	0.0	3.7	2.87	32	134	3
	3.5						0.6	0.0	12.4	2.93	40	106	6
	4.5	9.34	9.57	51.62	27.64		0.4	0.0	4.2	3.15	31	139	1
	6.5	9.43	9.85	53.11	28.01		0.5	0.0	7.9	3.55	166	212	9
	8.5	7.33	9.67	51.89	23.53		0.3	0.0	3.5	6.46	461	399	16
	10.5	6.03	9.16	49.52	21.23		0.2	0.0	5.0	7.97	732	477	31
	13.5	6.53	9.51	51.15	22.24		0.2	0.0	2.9	8.23	792	490	38
	0.25	9.70	9.85	53.41	28.71		0.4	1.6	36.1	3.05	0	67	0
	0.75	9.88	10.03	54.46	29.33		5.7	8.3	5.2	3.53	41	158	1
	2.5	9.76	10.13	54.92	29.10		5.4	6.7	5.1	3.39	165	237	6
BPC 8	3.5	10.01	10.43	55.98	29.91			1.8	9.1	3.42	100	192	5
	4.5	9.66	10.00	53.72	28.29		1.6	0.0	6.8	3.13	0	171	0
	6.5	9.80	10.19	55.16	29.03		2.7	0.0	6.8	3.36	138	226	7
	8.5	9.07	9.73	52.64	26.60		0.9	0.0	5.3	3.98	229	324	10
	10.5	8.99	9.42	51.51	26.07		1.3	0.1	4.7	4.63	268	401	14
	13.5	9.19	9.70	53.04	27.13		1.0	0.2	4.9	4.54	313	433	17
	16.5	8.98	9.56	51.96	26.56		0.3	0.2	5.2	4.65	680	433	19
	0	10.28	10.43	55.57	30.04			0.0		2.29	0	15	0
	0.25	10.11	10.12	54.29	28.85		6.7	6.0	6.6	3.03	0		2
	0.75						7.3	6.6	11.6	3.08	8	171	0
	1.25						10.8	10.2	3.9	2.95	18	188	0
	1.75						17.1	6.0	5.5	3.22	56		10
	2.5						12.7	4.4	4.2	3.40	41	185	0
	3.5						4.7	2.3	6.1	3.31	49	185	0
	4.5	9.44	9.69	51.48	27.19		1.7	1.1	3.9	3.36	53	197	0
	6.5	10.07	10.49	54.74	28.46		0.3	0.4	4.5	3.11	100	185	3
	8.5	10.83	10.87	55.85	29.23		1.0	0.6	5.4	3.51	119	236	6
	10.5	10.86	11.03	57.06	29.85		1.0	1.6	20.5	3.26	116		

Table 5-30. Major element composition.

Core	depth (cm-bsf)	CaO (%)	Al <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	K <sub>2</sub> O (%)	MgO (%)	SiO <sub>2</sub> (%)
SLA	0.3	21.3	9.6	1.5	8.2	0.7	3.2	26.5
	0.8	26.3	7.1	1.2	6.9	0.2	2.9	18.8
	1.5	19.1	10.2	1.4	8.2	0.3	3.3	26.8
	2.5	21.8	11.5	1.6	9.0	0.3	3.4	30.4
	3.5	21.4	10.4	1.5	8.7	0.2	3.4	27.9
	4.5	23.0	9.4	1.4	8.2	0.2	3.1	24.9
	5.5	31.9	7.6	1.3	7.3	0.1	3.1	20.4
	6.5	24.2	9.0	1.4	8.0	0.2	3.1	24.8
	7.5	24.0	8.0	1.3	7.6	0.2	3.0	22.2
	8.5	20.6	9.6	1.4	7.9	0.3	3.1	26.0
	9.5	23.7	9.2	1.5	8.4	0.2	3.3	25.4
	10.5	21.4	9.1	1.5	8.5	0.2	3.1	24.5
	11.5	23.8	9.2	1.4	8.1	0.2	3.1	24.7
	12.5	23.3	8.7	1.4	8.1	0.2	3.1	23.8
	13.5	27.5	8.1	1.3	7.7	0.2	2.9	21.3
	14.5	28.7	6.0	1.0	6.3	0.3	2.9	17.0
	16.5	29.8	7.5	1.2	7.1	0.2	2.8	19.7
SLB	0.3	20.7	9.8	1.4	8.2	0.3	2.8	27.0
	0.8	21.1	9.5	1.4	8.3	0.3	2.8	25.8
	1.3	20.9	10.2	1.5	8.5	0.2	3.0	27.5
	1.8	20.9	9.8	1.4	8.3	0.3	2.9	24.8
	2.5	18.1	9.8	1.3	7.5	0.3	2.7	24.3
	3.5	19.9	10.7	1.4	8.3	0.2	3.1	27.3
	4.5	18.7	10.4	1.4	8.0	0.3	3.1	27.5
	6.0	23.3	9.9	1.5	8.0	0.3	3.2	26.7
	7.5	20.0	10.4	1.5	7.4	0.2	3.1	27.7
	9.0	22.0	9.3	1.4	8.3	0.2	3.0	25.1
	10.5	18.7	9.0	1.4	7.2	0.2	2.6	25.5
	12.0	20.2	8.7	1.4	7.7	0.3	2.7	24.3
	13.5	22.7	10.6	1.5	8.1	0.4	3.2	28.2
	15.0	23.2	8.4	1.3	7.7	0.2	2.8	23.1
	16.5	21.6	10.0	1.4	8.1	0.2	3.0	26.6
	18.0	22.0	8.4	1.3	7.5	0.2	2.8	21.6
	19.5	20.3	10.0	1.4	7.9	0.2	3.0	26.9
	21.0	23.3	8.7	1.4	8.1	0.3	3.0	23.3
SLC	0.3	21.0	10.0	1.5	8.4	0.2	2.9	26.0
	0.8	20.8	9.4	1.5	8.4	0.2	2.9	25.6
	1.3	21.6	9.7	1.5	8.7	0.3	3.0	26.3
	1.8	22.4	9.7	1.5	8.6	0.2	3.1	27.2
	2.5	19.6	9.7	1.4	9.0	0.2	2.9	26.3
	6.5	20.9	9.8	1.5	8.6	0.1	3.0	25.9
	7.5	22.6	9.0	1.5	8.4	0.1	3.0	24.4
	8.5	23.0	10.0	1.5	8.6	0.2	3.0	26.2
	9.5	21.6	8.9	1.5	8.0	0.3	3.0	23.9
	10.5	20.1	9.9	1.5	8.6	0.2	3.0	26.1
	11.5	21.6	8.4	1.4	7.8	0.2	2.8	22.6
	12.5	19.0	10.6	1.5	8.4	0.2	3.2	27.5
	13.5	23.6	9.2	1.5	8.4	0.4	3.2	24.3
	14.5	18.6	10.6	1.4	8.2	0.3	3.2	26.6
	16.0	23.3	9.2	1.5	8.5	0.2	3.2	24.8
	17.5	21.1	10.7	1.5	8.1	0.3	3.5	27.3
	19.0	21.9	9.1	1.5	8.5	0.2	3.1	25.0
	20.5	20.0	11.5	1.6	8.6	0.3	3.6	29.3
	14.5	18.6	10.6	1.4	8.2	0.3	3.2	26.6
	16.0	23.3	9.2	1.5	8.5	0.2	3.2	24.8
	17.5	21.1	10.7	1.5	8.1	0.3	3.5	27.3
	19.0	21.9	9.1	1.5	8.5	0.2	3.1	25.0
	20.5	20.0	11.5	1.6	8.6	0.3	3.6	29.3

## Major element composition (cont.).

Core	depth (cm-bsf)	CaO (%)	Al <sub>2</sub> O <sub>3</sub> (%)	TiO <sub>2</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	K <sub>2</sub> O (%)	MgO (%)	SiO <sub>2</sub> (%)
BPA	0.3	33.4	3.2	0.5	3.3	0.1	2.6	10.8
	0.8	38.0	3.8	0.6	3.8	0.1	3.0	11.9
	1.3	36.4	3.6	0.6	3.6	0.0	2.8	10.9
	1.8	33.8	3.0	0.5	3.3	0.1	2.6	8.8
	2.5	35.6	3.4	0.5	3.6	0.1	2.7	10.1
	4.5	38.2	3.7	0.6	3.4	0.1	3.0	11.4
	5.5	34.2	3.2	0.5	3.1	0.1	2.7	9.1
	6.5	35.9	3.5	0.6	3.5	0.1	2.9	9.8
	7.5	36.5	3.5	0.5	3.5	0.1	2.9	9.1
	8.5	31.3	2.8	0.5	3.6	0.2	2.3	9.2
	9.5	35.9	3.5	0.6	4.0	0.2	2.9	10.9
	10.5	36.7	3.5	0.6	3.8	0.1	2.8	10.3
	12.0	35.2	3.0	0.5	3.3	0.1	2.5	9.8
	13.5	37.2	3.5	0.6	3.7	0.0	2.8	10.7
BPB	0.3	40.3	2.3	0.4	3.1		2.3	7.6
	0.8	41.2	2.3	0.4	2.9	0.1	2.3	7.2
	1.3	40.2	2.4	0.4	3.0	0.1	2.4	7.6
	1.8	42.6	2.6	0.5	3.2	0.1	2.7	8.5
	2.5	42.5	2.3	0.4	2.9	0.0	2.4	7.1
	3.5	43.9	2.6	0.5	3.0	0.0	2.6	8.5
	4.5	40.6	2.4	0.4	2.9	0.0	2.4	8.2
	5.5	40.3	2.4	0.4	3.0	0.1	2.4	8.0
	6.5	38.0	2.2	0.4	2.8		2.3	6.4
	7.5	46.4	2.2	0.4	2.8	0.0	2.3	6.4
	8.5	40.0	2.0	0.4	2.5		2.1	5.5
	9.5	39.9	2.4	0.4	3.0	0.1	2.4	7.4
	10.5	38.9	2.3	0.5	3.0	0.0	2.4	7.2
	12.0	36.8	2.4	0.4	2.9		2.5	7.2
	13.5	38.1	2.3	0.4	2.7	0.0	2.2	6.5
	15.0	37.5	2.3	0.4	2.8	0.0	2.3	6.7
	16.5	40.8	2.7	0.5	3.2	0.0	2.5	7.6
BPC	0.3	41.2	2.3	0.4	3.0	0.2	2.1	6.0
	0.8	42.0	2.1	0.4	2.8		1.9	6.1
	1.3	47.3	2.4	0.5	3.1	0.2	2.1	6.5
	1.8	42.6	2.3	0.5	3.0	0.1	2.0	6.1
	2.5	42.7	2.3	0.5	2.9		2.0	6.6
	3.5	39.8	1.8	0.4	2.5		1.9	5.3
	4.5	43.6	2.1	0.4	2.9		2.0	5.9
	5.5	45.4	2.5	0.5	3.2	0.0	2.2	6.7
	6.5	42.5	2.3	0.5	3.1	0.0	1.9	6.3
	7.5	41.9	1.9	0.4	4.3	0.1	1.8	4.5
	8.5	43.2	2.1	0.4	2.8		1.7	4.9
	9.5	42.4	2.3	0.5	3.0		1.9	5.9
	12.0	42.4	2.4	0.5	3.3	0.1	1.5	5.5
	13.5	41.9	3.4	0.7	4.3	0.2	1.4	7.4
	15.0	40.2	3.1	0.7	3.9	0.1	1.5	7.2

Table 5-31. Trace elemental concentrations.

SAMPLE	depth cm-bsf	Cr (µg/g) (µg/g)	Mn (µg/g) (µg/g)	Ni (µg/g) (µg/g)	Cu (µg/g) (µg/g)	Zn (µg/g) (µg/g)
SLA	0.25	175	613	76	409	270
	0.75	168	558	72	293	493
	0.75	193	659	76	379	373
	1.50	180	644	87	617	373
	2.50	178	632	82	516	360
	3.50	172	610	86	451	367
	4.50	165	555	68	357	350
	5.50	137	462	52	414	217
	6.50	169	544	46	287	358
	7.50	158	493	55	309	295
	8.50	177	590	73	451	331
	9.50	166	503	67	440	283
	10.50	187	569	74	392	319
	11.50	171	548	71	435	292
	12.50	164	519	55	322	388
	13.50	158	497	69	388	374
	14.50	135	432	55	250	372
	16.50	150	481	56	244	254
SLB	0.25	195	643	70	383	268
	0.75	191	614	84	372	372
	1.25	183	619	85	485	312
	1.75	187	620	86	518	307
	2.50	180	636	74	484	401
	3.50	189	633	88	531	418
	4.50	190	632	89	520	312
	6.00	178	566	40	218	362
	7.50	181	601	46	268	319
	9.00	183	568	30	241	395
	10.50	168	576	42	253	307
	12.00	186	578	69	332	289
	13.50	183	606	77	579	284
	15.00	172	538	58	314	369
	16.50	187	604	70	418	354
	18.00	192	572	64	390	318
	19.50	174	602	81	496	401
	21.00	171	571	104	363	438
SLC	0.25	178	676	65	342	343
	0.75	182	678	61	345	378
	1.25	177	646	70	342	377
	1.75	179	665	59	330	406
	2.50	178	673	68	402	384
	6.50	174	582	77	447	424
	7.50	204	562	76	419	424
	8.50	188	638	82	525	433
	9.50	180	573	59	330	509
	10.50	182	619	77	576	409
	11.50	181	562	65	330	383
	12.50	180	652	80	424	389
	13.50	176	597	64	340	297
	14.50	181	650	85	423	367
	16.00	174	594	69	354	287
	17.50	177	677	83	225	227
	19.00	175	609	84	177	153
	20.50	183	631	89	225	244



## Trace elemental concentrations (cont.).

SAMPLE	depth cm-bsf	Cr (µg/g) (µg/g)	Mn (µg/g) (µg/g)	Ni (µg/g) (µg/g)	Cu (µg/g) (µg/g)	Zn (µg/g) (µg/g)
BPA	0.25	72	241	29	271	169
	0.75	81	216	31	193	212
	1.25	80	213	28	205	302
	1.75	72	211	28	233	260
	2.50	81	215	32	267	211
	4.50	79	216	31	248	308
	5.50	79	207	40	262	254
	6.50	91	214	33	298	258
	7.50	75	207	30	280	212
	8.50	80	209	34	307	258
	9.50	89	220	43	333	223
	10.50	80	289	32	322	290
	12.00	75	207	27	240	225
	13.50	104	232	30	240	304
BPB	0.25	59	195	34	536	222
	0.75	70	188	21	159	224
	1.25	62	197	23	208	197
	1.75	63	216	23	188	400
	2.50	64	184	20	65	190
	3.50	59	175	18	63	199
	4.50	59	174	24	150	187
	5.50	75	178	23	196	213
	6.50	57	167	22	169	170
	7.50	56	158	23	137	178
	8.50	55	159	18	112	194
	9.50	65	177	21	194	188
	10.50	88	187	24	316	321
	12.00	69	179	27	431	166
	13.50	72	168	22	216	194
	15.00	64	185	24	198	232
	16.50	86	189	27	227	285
BPC	0.25	59	188	21	207	129
	0.75	63	189	20	180	153
	1.25	69	199	21	111	430
	1.75	65	193	22	110	391
	2.50	61	188	27	93	192
	3.50	63	179	28	138	131
	4.50	59	173	21	123	183
	5.50	61	183	25	129	197
	6.50	74	194	23	116	165
	7.50	126	210	28	196	456
	8.50	56	195	25	107	120
	9.50	63	182	24	149	173
	12.00	74	225	29	113	125
	13.50	89	303	39	52	18
	15.00	96	319	53	32	35

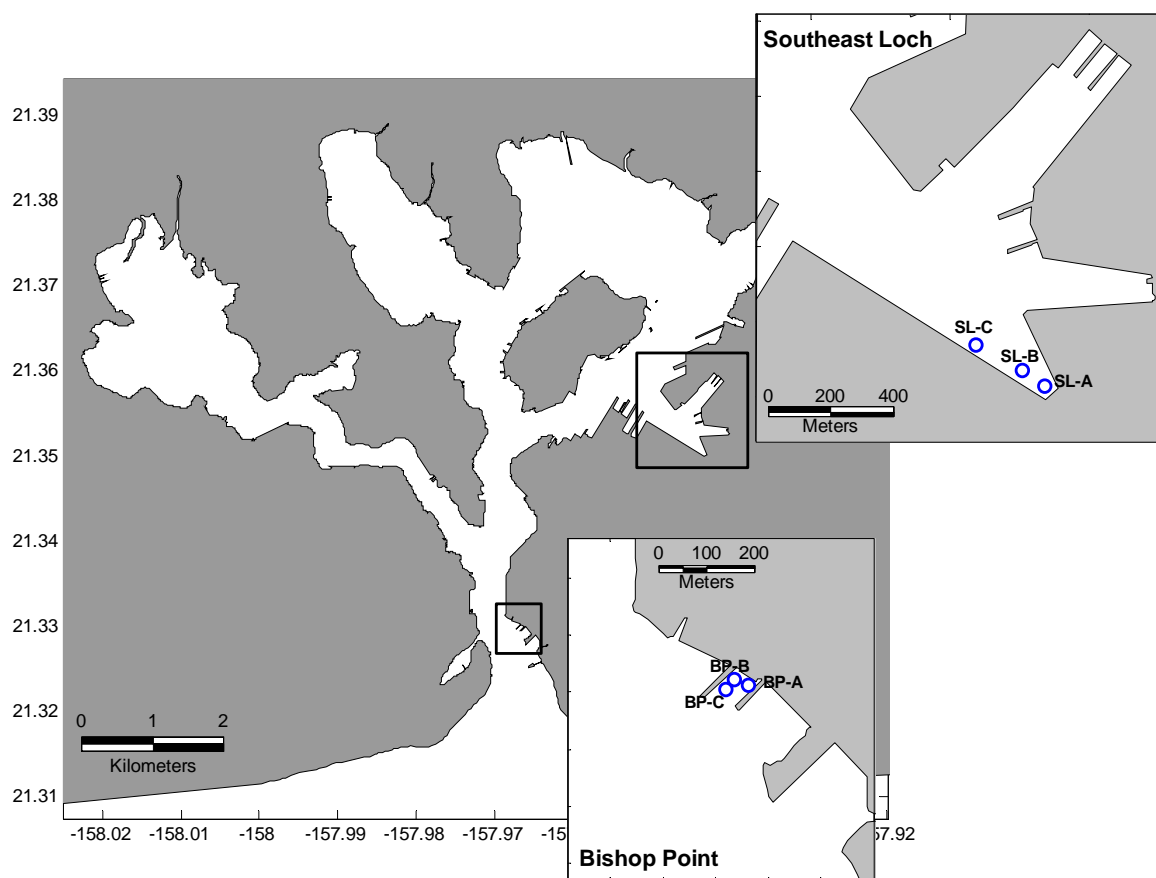


Figure 5-120. Core station locations in Pearl Harbor.

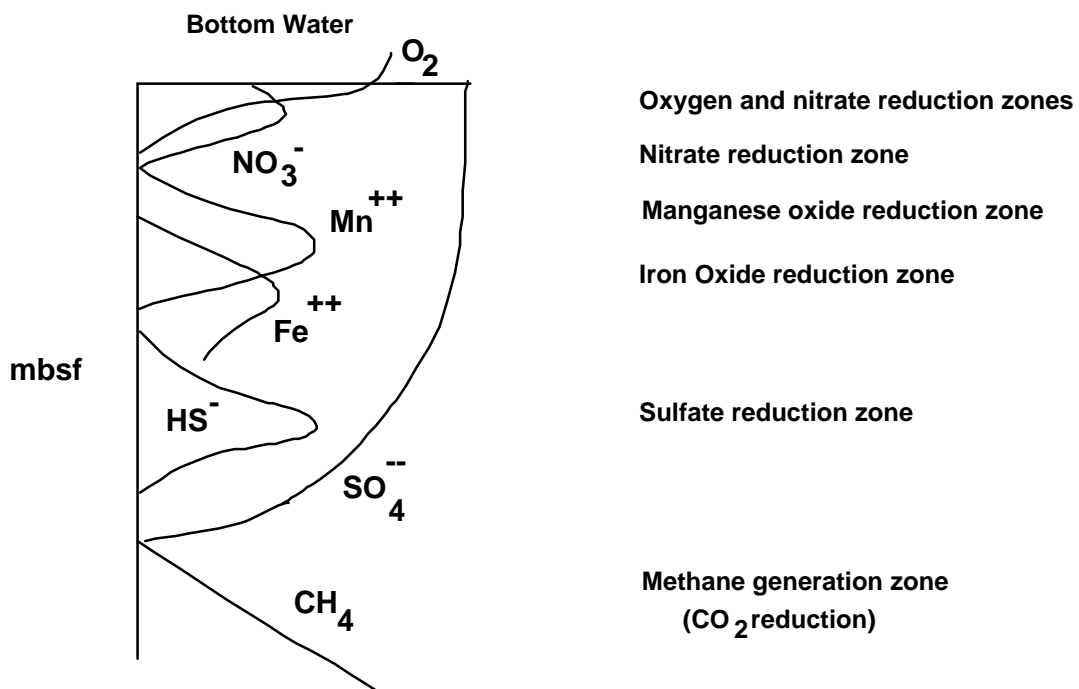


Figure 5-121. Reduction sequence of organic carbon oxidants in pore waters.

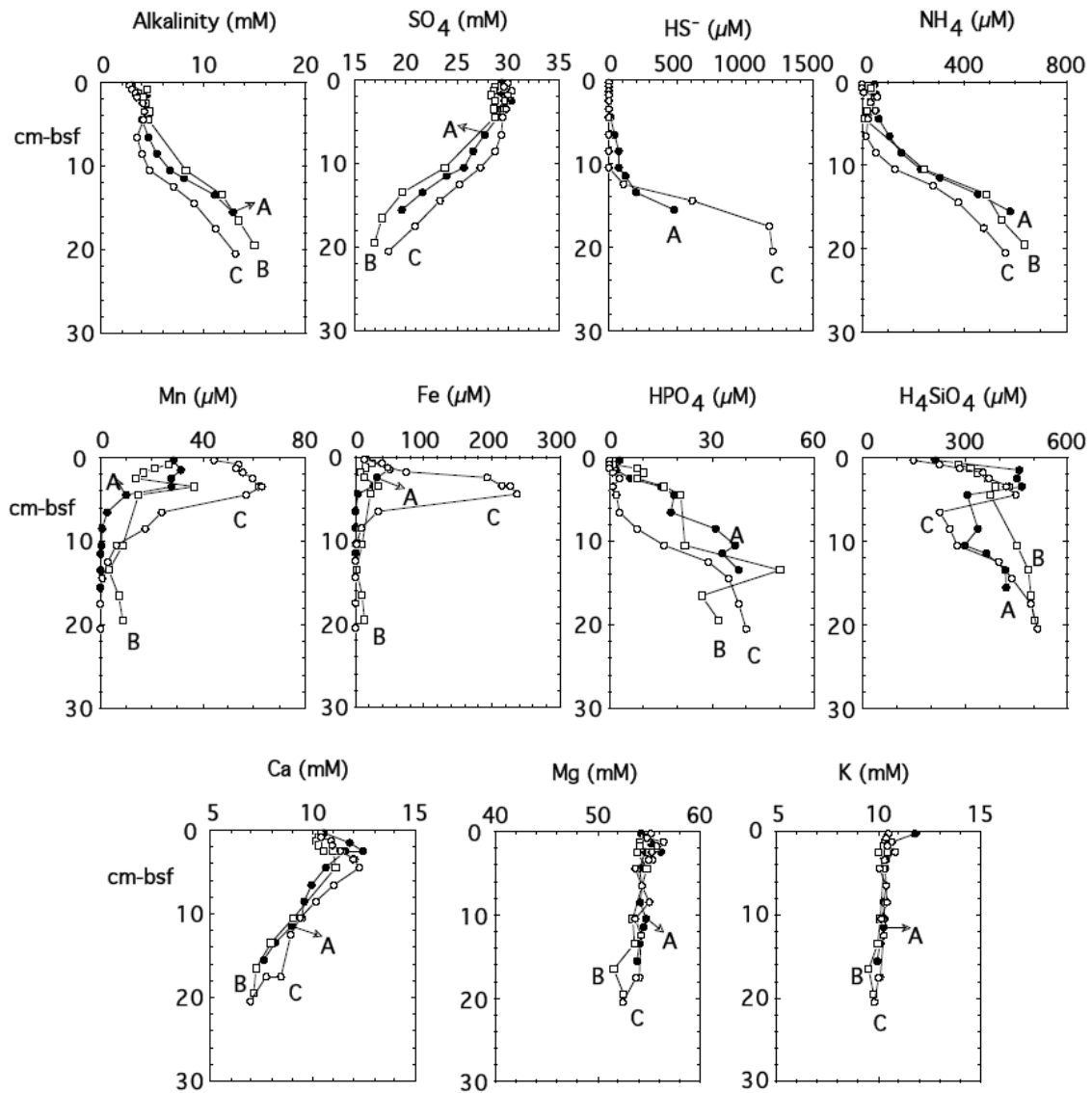


Figure 5-122. Figure 4. Pore water chemistry in Merry Point cores (South-East Loch).

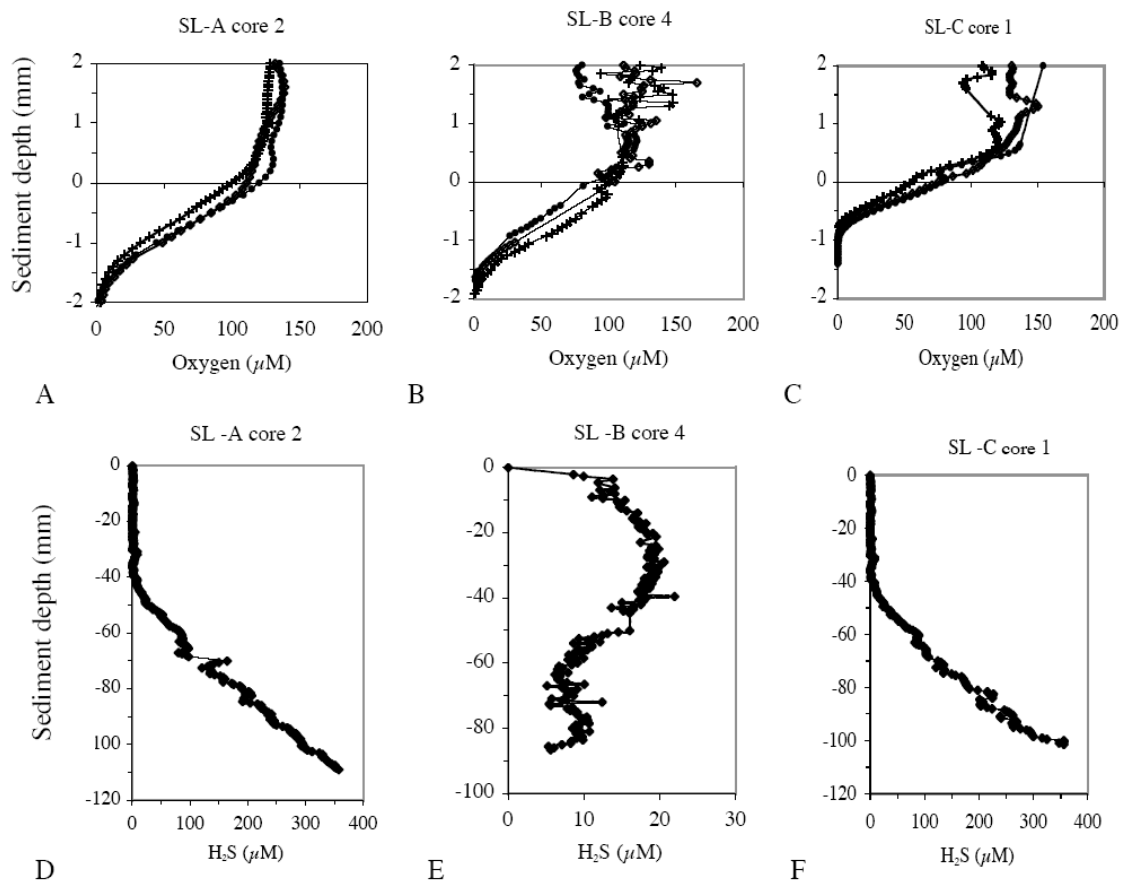


Figure 5-123. Figure 5. Micro-profiles of O<sub>2</sub> (A-C) and H<sub>2</sub>S (D-F) concentrations measured in cores taken at the three locations A, B, and C at Station Merry Point (South-East Loch).

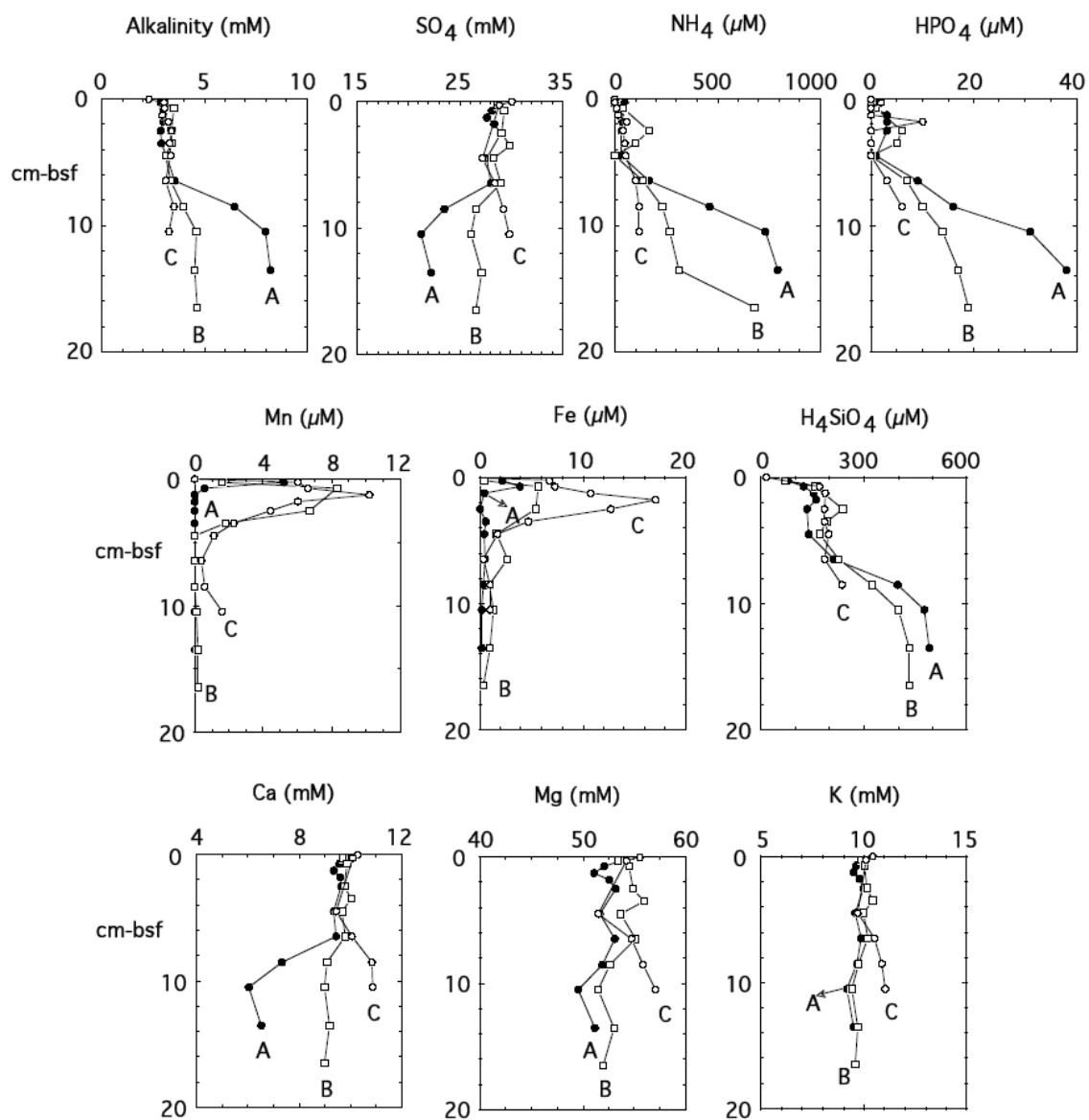


Figure 5-124. Figure 6. Pore water chemistry in Bishop Point cores.

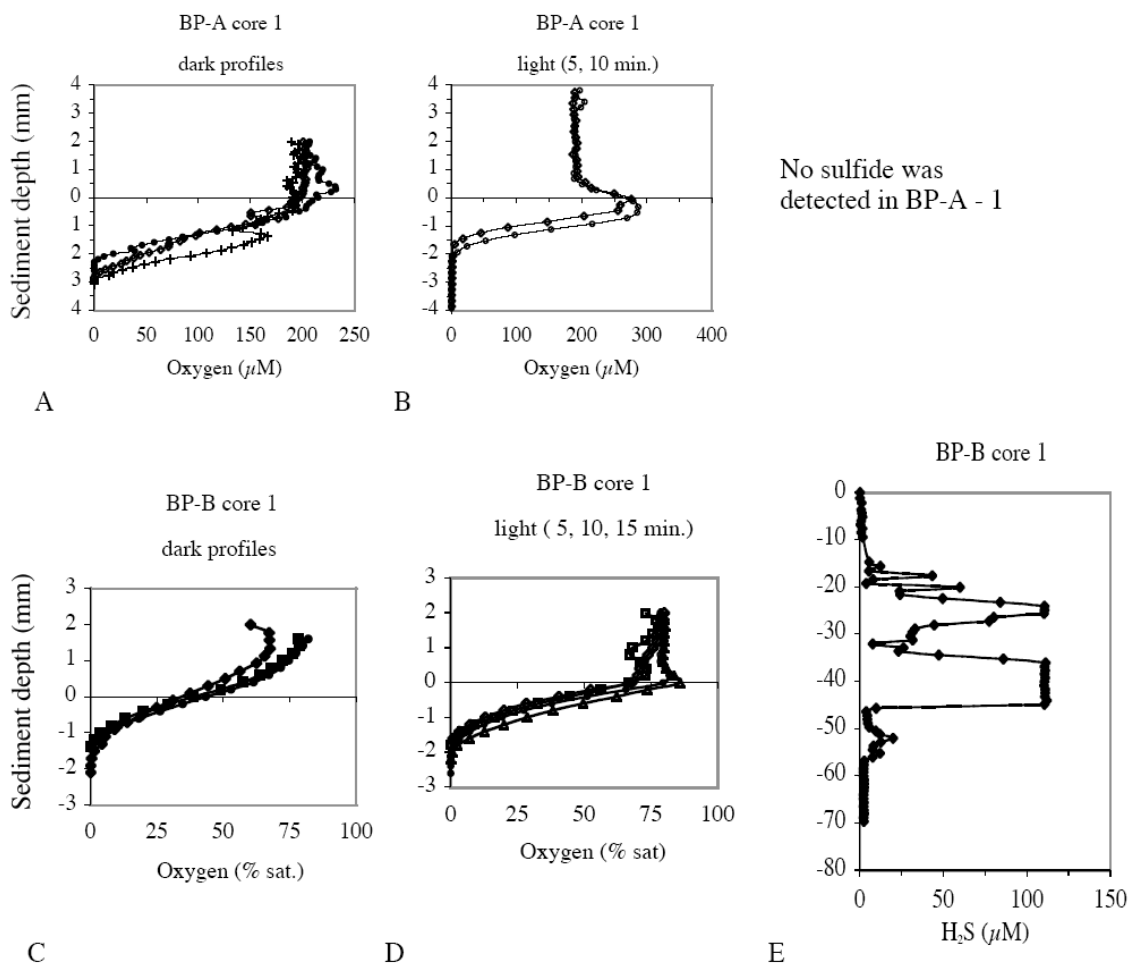


Figure 5-125. Figure 7. A&B: Oxygen profiles in BP-A 1 under dark (A) and light (B) conditions; no sulfide was detected in core BP-A 1. C&D: Oxygen profiles measured in core BP-B 1 under dark (C) and light (D) conditions. E: Sulfide concentrations measured in core BP-B 1.

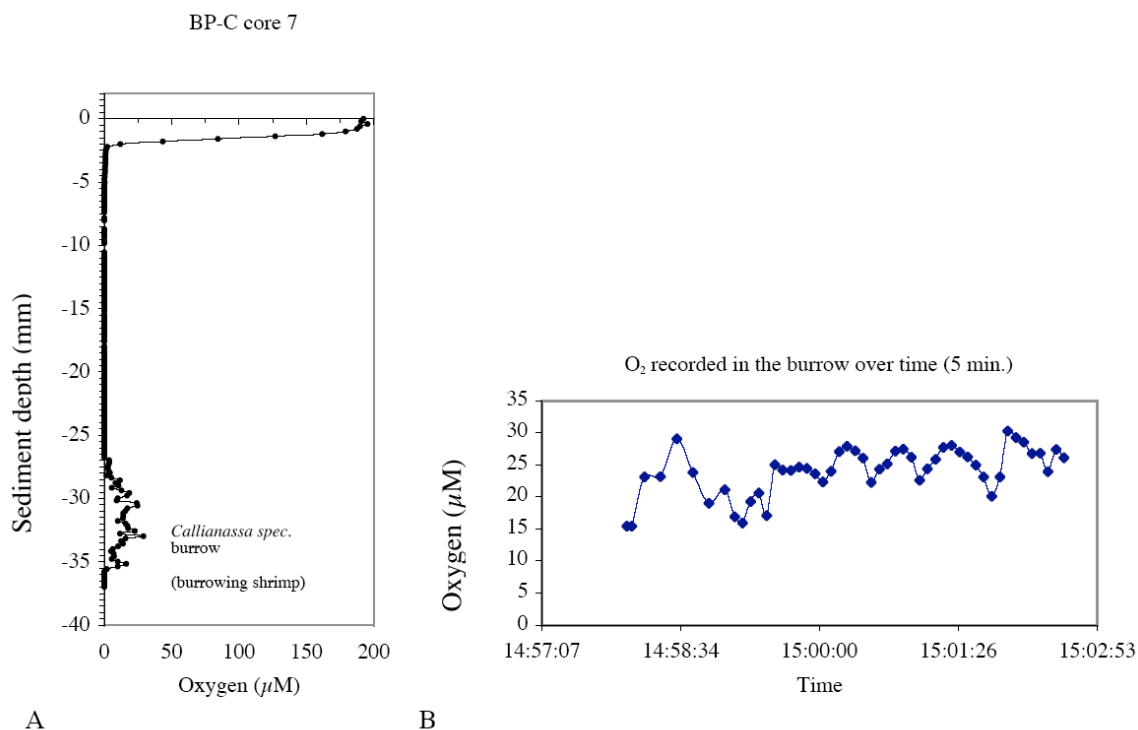


Figure 5-126. Figure 8. A: Oxygen profile in core BP-C 7 containing a burrowing shrimp (*Callianassa spec.*). B: Oxygen concentration measured over time in the burrow at 33 mm sediment depth.

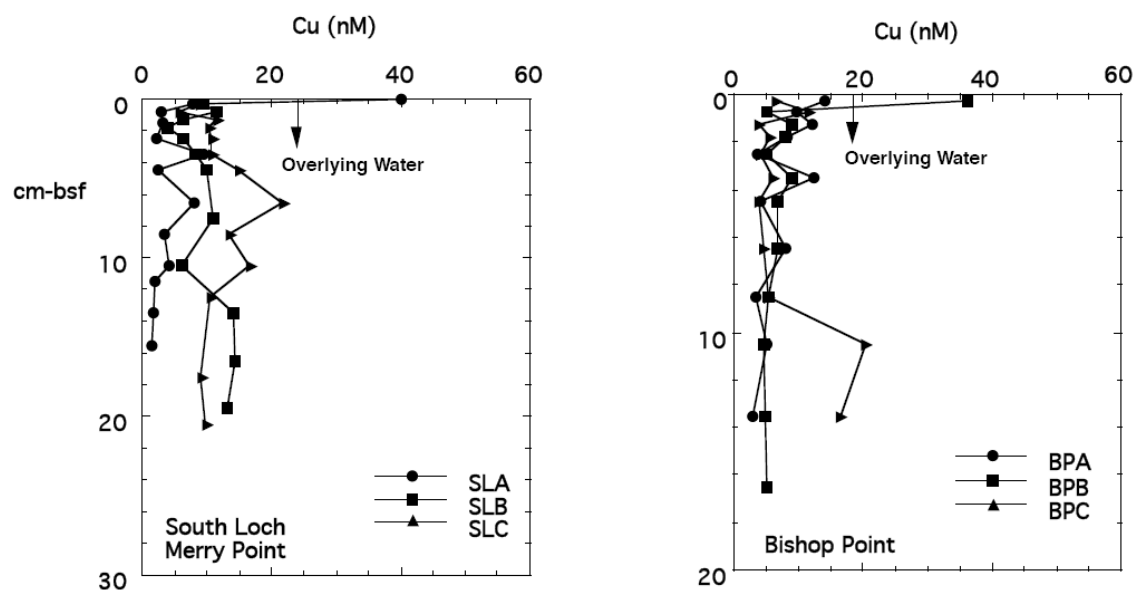


Figure 5-127. Figure 9. Dissolved copper concentration depth profiles at Merry Point and Bishop Point.



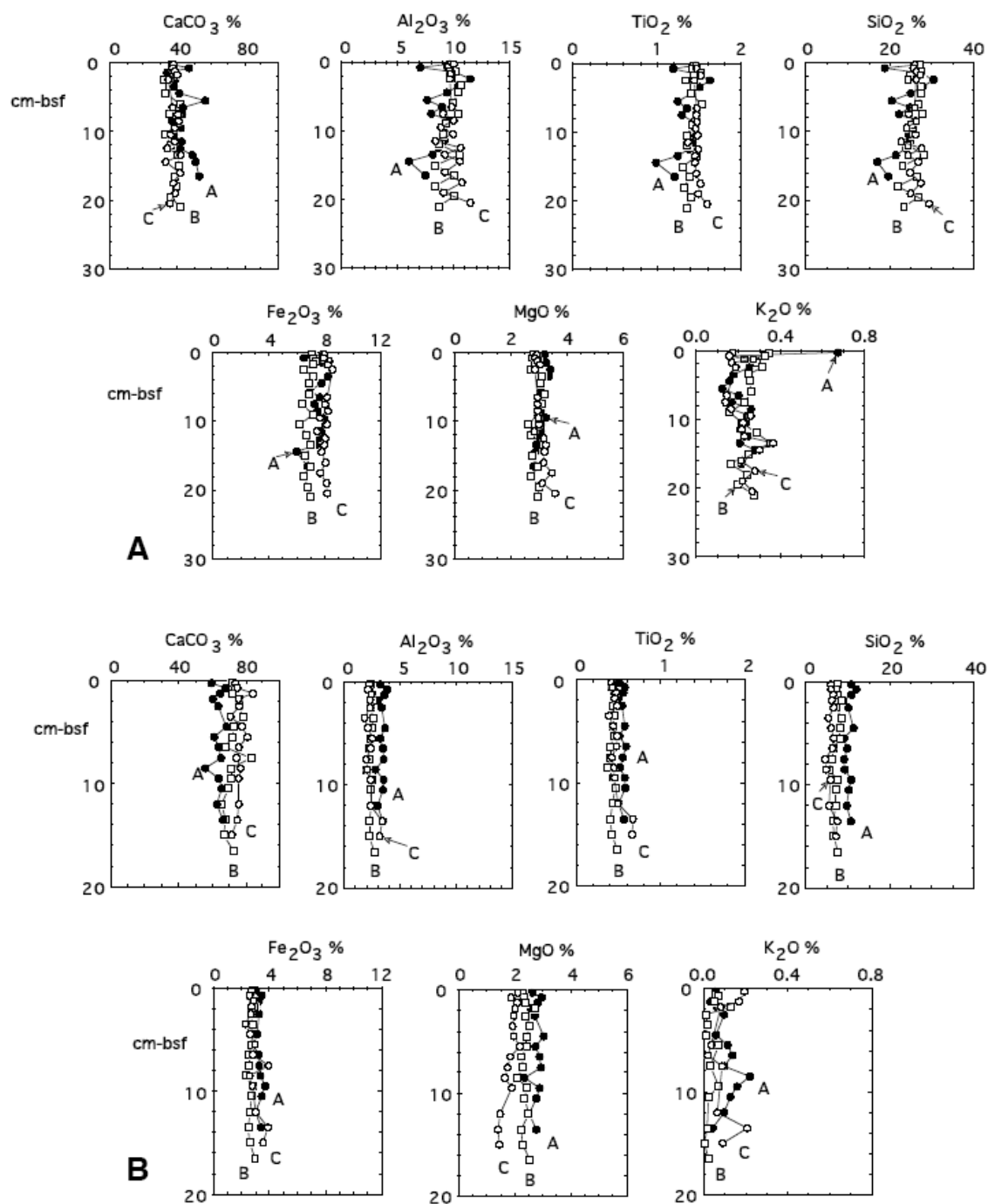


Figure 5-128. Figure 10. Major constituents in cores at Merry Point (A) and Bishop Point (B) (note:  $\text{CaO}$  calculated as  $\text{CaCO}_3$ ).

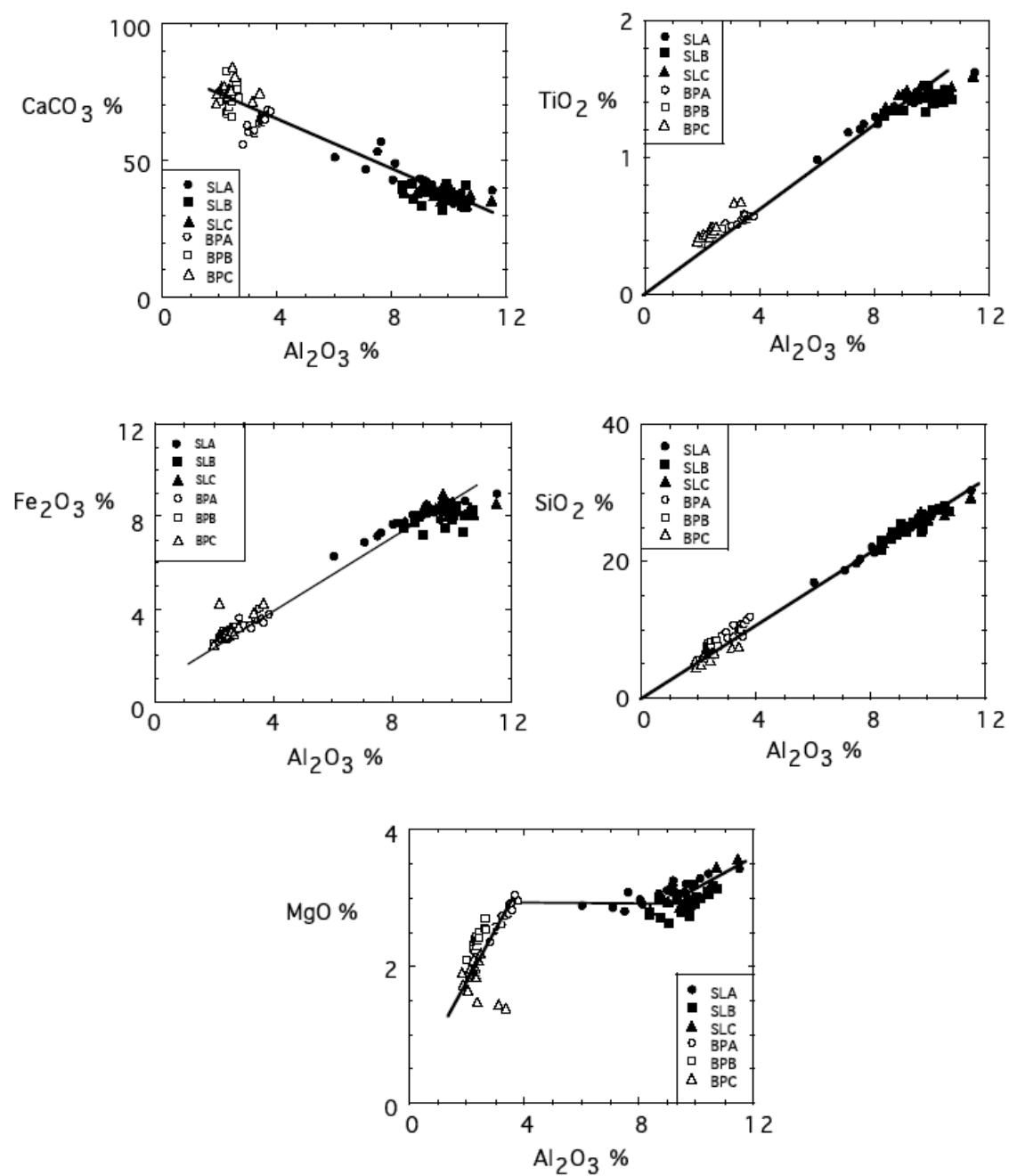


Figure 5-129. Figure 11. Major element correlations with  $\text{Al}_2\text{O}_3$  as denominator.

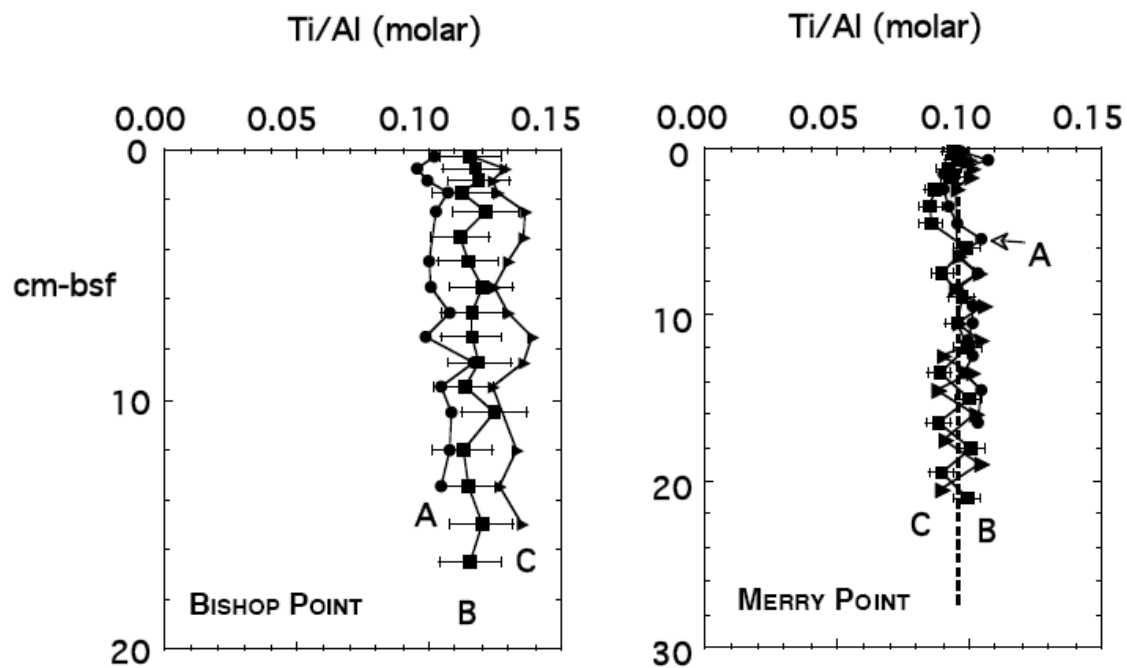


Figure 5-130. Figure 12. Ti/Al (molar) ratios in Merry Point and Bishop Point sediments.

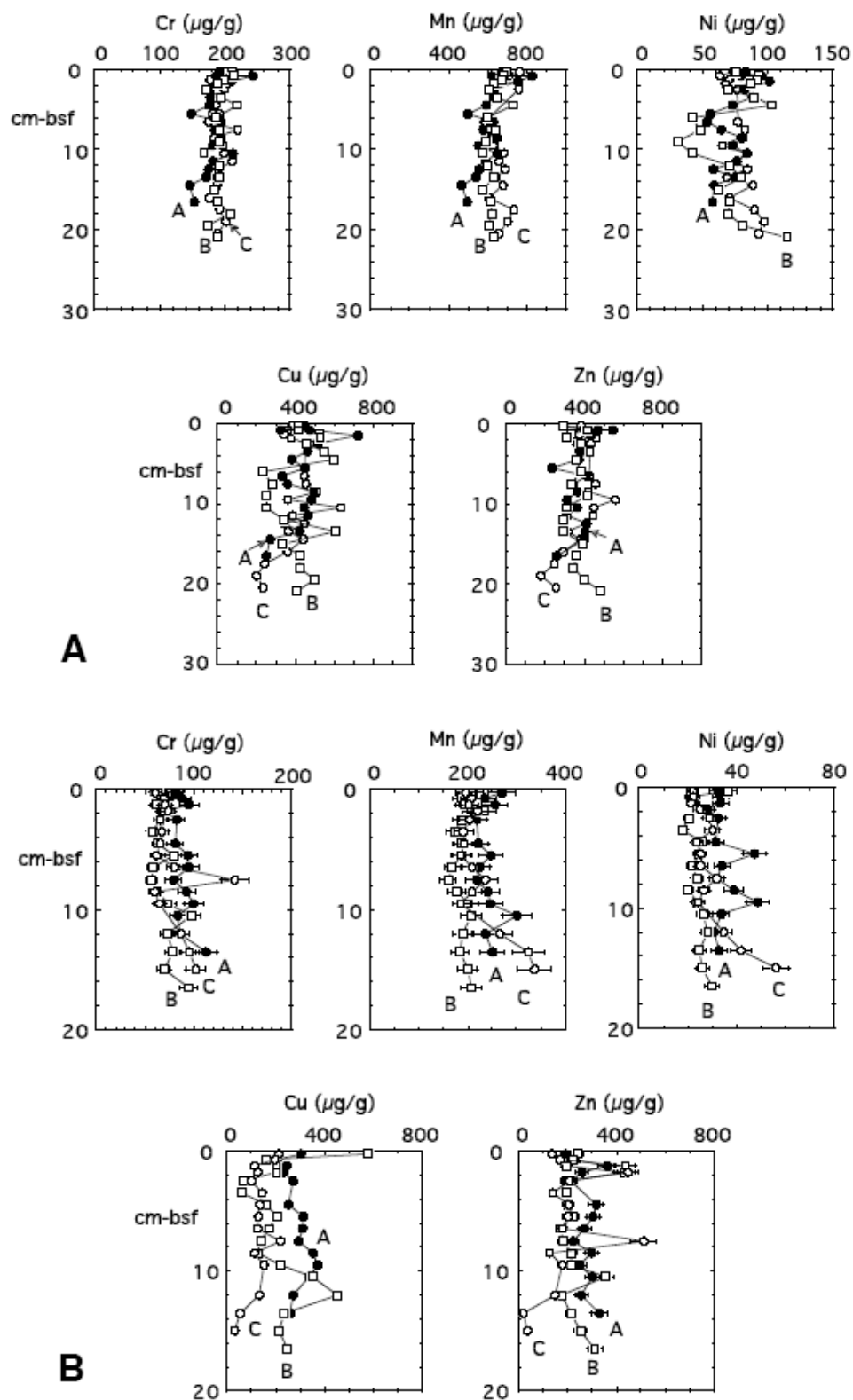


Figure 5-131. Figure 13. Minor element concentration in solid phases of Merry Point (A) and Bishop Point (B) Cores.

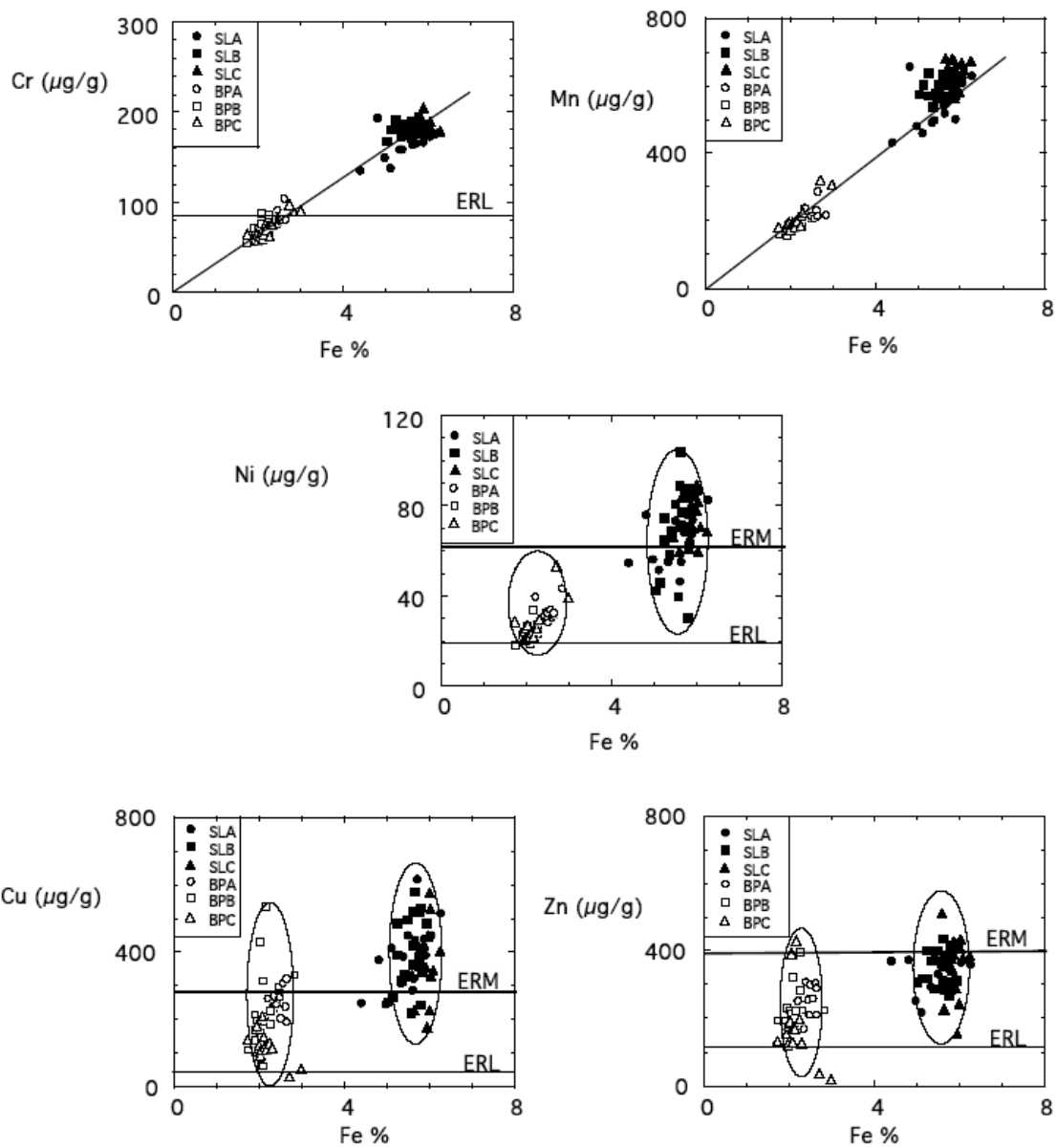


Figure 5-132. Figure 14. Correlation of Fe % contents with trace metals in Merry Point and Bishop Point cores.

## 5.10 EVALUATION OF SEDIMENTATION BY SEDIMENT TRAP AND AGE-DATED CORES

### Methods

#### Sediment Traps

Sediment traps were constructed of 6 in. diameter PVC tubing with an aspect ratio of 5:1, for a trap height of 30 inches. Each trap was filled with ~4 L of a solution consisting of 50ppt brine, sodium azide (5%) to prevent biological growth, and Rhodamine dye to exhibit any disturbance of the trap during the deployment. The remaining volume of each trap was carefully filled with approximately 10 L of ambient seawater.

Prior to deployment, each trap was capped to minimize disturbance during the deployment procedure. Traps were deployed by diver at each site, and clamped onto a metal stake for vertical stability. Once in place, traps were left in place with the caps on for ~24 hours to allow any sediment that was disturbed during the deployment to settle. Each trap was then carefully uncapped by a diver and left in place for the remaining time of the deployment.

Three traps were deployed at each site and were left in the field for approximately 17 days at Bishop Point and 18 days at Southeast Loch (Figure 5-133). At the time of recovery, a diffuse but discernible interface separating the layer containing Rhodamine dye and overlying seawater layer could be seen in the bottom half of the trap. Separation of particulates from the brine solution was by done by repeated intervals of settling and carefully decanting. Final isolation of the sediment was by centrifugation in a 500 mL centrifuge bottle. The sediment was allowed to dry at room temperature with a gentle stream of air directed at the sediment pellet inside of the centrifuge bottle. The remaining dry sediment was carefully removed from the bottle, weighed, and sub-sampled for characterization and analysis. Sedimentation rates were calculated based on the dry weight of sediments collected during the deployment period. Laboratory analyses of PAH and metal concentrations were also done.

#### Core Collection

Cores for  $^7\text{Be}$  and  $^{137}\text{Cs}$  were collected using the multicore sampler. This sampler is designed to collect up to four cores simultaneously at very close spatial resolution. Each core was approximately 24 cm in length, and was sliced into sections for age dating and chemical analyses for metals and PAHs. To assess longer-term deposition, cores for  $^{210}\text{Pb}$  dating were collected using 122 cm core tubes that were inserted into the sediment by divers. Sediment cores retrieved were approximately 55 cm in length and were sliced into sections for age dating and chemical analyses.

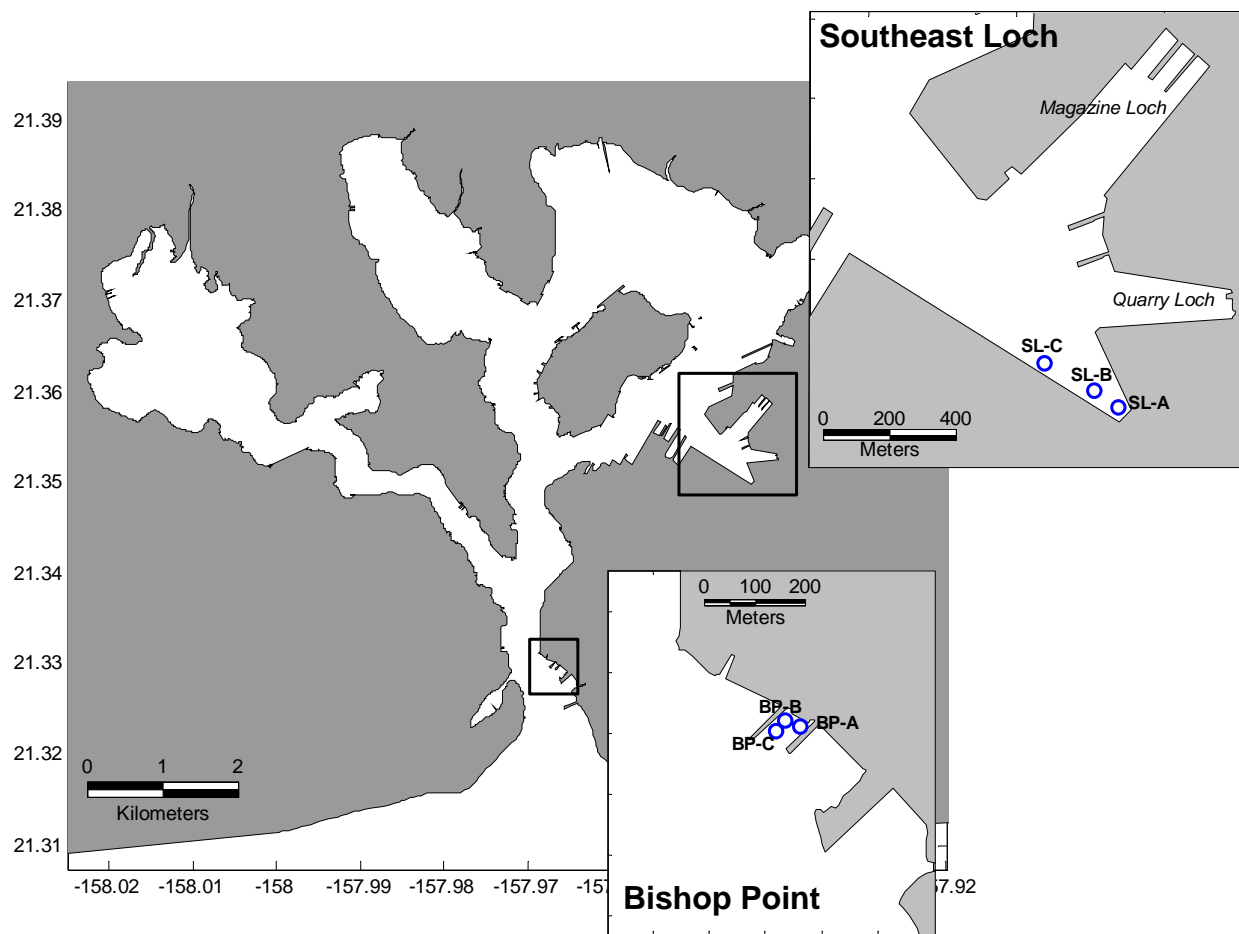


Figure 5-133. Map of Pearl Harbor showing the locations of sediment trap deployments at the Southeast Loch and Bishop Point sites.

## Results

### Percent Dry Weight

Both the BP-C and SL-C cores show a fairly constant increase in percent dry weight (%DW) with depth, likely suggesting a combination of coarsening and compaction down-core (Figure 5-134). %DW for the SL-C core was ~%20 lower than that for the BP-C core, suggesting that finer grained sediments were present in that core. This is consistent with the results of organic carbon (TOC) analysis in which greater organic carbon content was measured in the down-core sections of the SL-C core (Figure 5-135). Fine grain sediments are generally characterized by a greater organic carbon content.

### $^7\text{Be}$ Activity

No  $^7\text{Be}$  was detected in either of the cores.  $^7\text{Be}$  is a short-term isotope with a 53.3 day half-life. This method provides dating on recent sediments deposited within approximately 9 months, showing evidence that no sediment had been deposited within that time period at either coring location.

### <sup>137</sup>Cs Activity

<sup>137</sup>Cs activity in both cores show a decrease in <sup>137</sup>Cs levels down-core below ~3cm. <sup>137</sup>Cs activity in both the SL-C and BP-C cores show that background levels were not reached until the very bottom of the core. A strong <sup>137</sup>Cs peak was not seen in either core, suggesting that sediments may have experienced a significant level of mixing, or that the Cs peak has been removed via dredging. As a result, <sup>137</sup>Cs activity cannot be used as a reference point for the <sup>210</sup>Pb age dating.

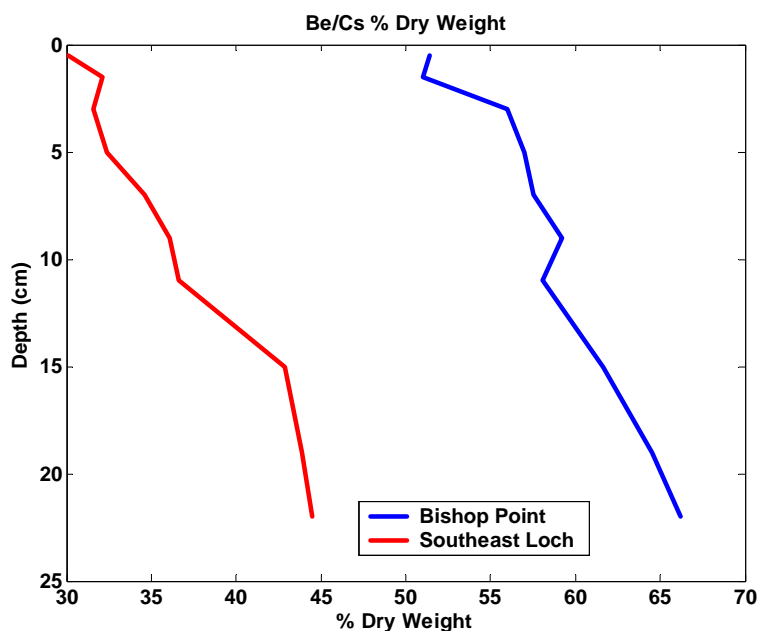


Figure 5-134. % Dry weight with depth for cores SLC (Red line) and BPC (Blue line)

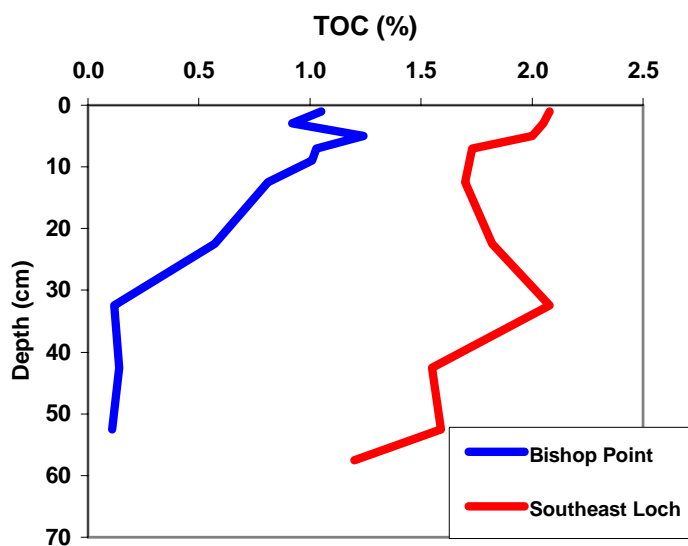


Figure 5-135. Total organic carbon



### **<sup>210</sup>Pb Activity**

Both cores showed a net decrease in <sup>210</sup>Pb activity levels with depth, suggesting that sediments are accumulating in this region (Figure 5-137). The rapid increase in <sup>210</sup>Pb activity at Bishop Point above ~22 cm is representative of more rapid sedimentation occurring after the construction of Hickam Field in 1938. A sub-surface peak in <sup>210</sup>Pb activity suggests that bioturbation or other anthropogenic mixing may be active at this site.

At Southeast Loch, <sup>210</sup>Pb activity decreases rapidly in the top 10 cm of the core and approaches background levels at ~12.5 cm. The background level was assumed to be 1.0 dpm/g. This profile may not be representative of the entire sediment record at Southeast Loch, as several dredging events have occurred in the area over the last decade. The most recent dredging event took place in 2002 in the Merry Loch area. It is likely that the top 12.5 cm of sediment are dredge residual, representing a mixture of sediments removed from the surface. Additionally, evidence of bioturbation was observed in SPI camera images to extend as deep as 15 cm. Sediments below the 12.5 cm horizon appear to be older sediments because of the low <sup>210</sup>Pb values and the flat profile with depth.

### **Sediment Accumulation Rates**

A sedimentation rate of 0.40 g/cm<sup>2</sup>/yr was measured at Bishop Point, with core sediments dating back to 1922 between 30 and 35 cm. Using a constant rate of deposition, a sedimentation rate of 0.05 g/cm<sup>2</sup>/yr was calculated Southeast Loch; however, dredging activity disturbs the sediment record and this value does not take that into account.

Sedimentation rates were also determined by the use of sediment traps deployed at the same stations. The traps were deployed for 18 days each. Results from these analyses are shown in

Table 5-32. Sedimentation rates determined from sediment trap analysis are significantly higher than those calculated using radioisotope age dating. This is could be a result of sediments settling into the traps due to resuspension events, higher accumulation than the long-term average in the traps during the deployment period related to wet weather discharges, or to disturbance of the long-term record (i.e. removal) in the sediment cores at the site by dredging events.

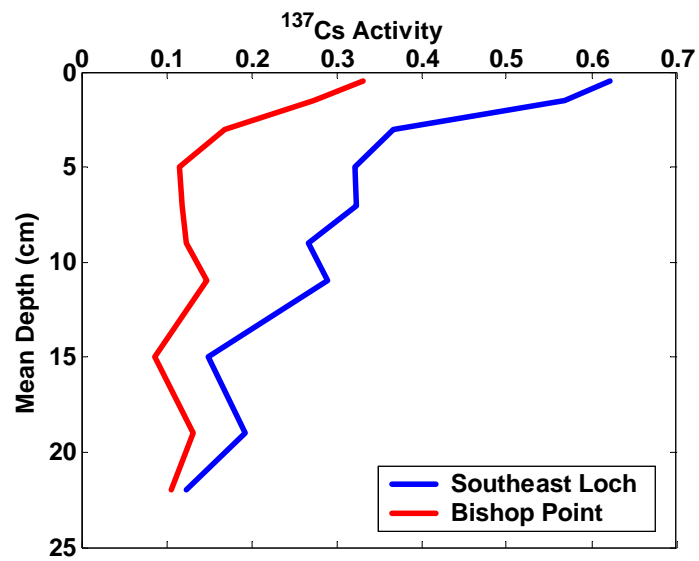


Figure 5-136.  $^{137}\text{Cs}$  activity levels (dpm/g).

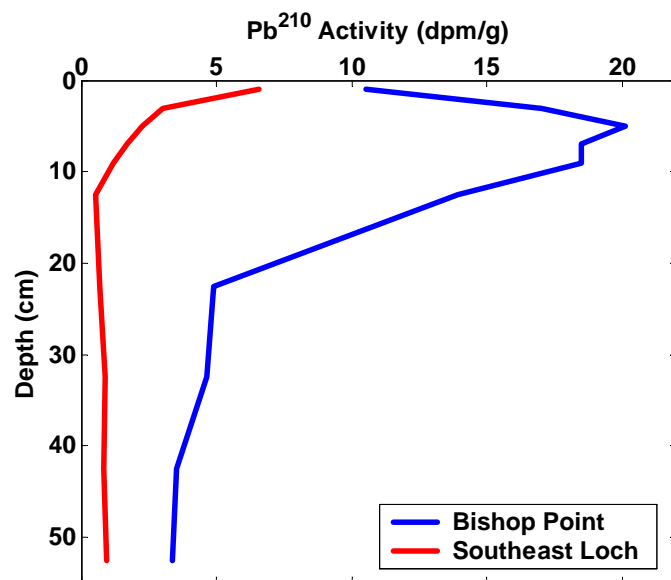


Figure 5-137.  $^{210}\text{Pb}$  activity levels.

Sample	Sedimentation Rate (g/cm <sup>2</sup> /yr)
BPC – Core	0.40
SLC – Core	0.05
BPC –Trap1	1.96
BPC –Trap2	2.50
BPC –Trap3	1.53
BPC –Trap Mean	2.00
SLC –Trap1	2.22
SLC –Trap2	1.05
SLC –Trap3	0.76
SLC –Trap Mean	1.35

Table 5-32. Sedimentation Rates calculated from age dating and sediment trap measurements.

### PAH Measurements

At Bishop Point, a sharp increase in PAH concentration is seen above 30 cm (Figure 5-138), likely a result of the completion of the Hickam Air Force Base. The concentration of all constituents approaches zero below 30 cm, signifying pre-industrial conditions. Extremely high concentrations (> 60,000 ng/g) for all constituents were observed at 7 cm depth, but have been omitted from the figure below (for scaling purposes). SLC shows minimal change in the concentration of heavy PAHs over the depth of the core, however light PAHs show an increase with depth. This observation is contrary to <sup>210</sup>Pb values that appear to reach background levels, indicating that they are ~75-100 years old and were deposited prior to the introduction of PAHs at the site. The enrichment of light PAHs throughout the bottom of the core is consistent with the PAH distribution in groundwater, suggesting that contaminated groundwater is being advected through the sediment. Seepage meter results also show that the Southeast Loch C station had the greatest amount of positive groundwater advection.

PAH concentrations were highly enriched in the sediment traps samples compared to the surface core sediments (0-2 cm) by as much as several orders of magnitude, particularly for the lower molecular weight PAHs (Figure 5-139). Though analyses are still in progress for this site, data suggest that rapid biodegradation is occurring during or just after deposition.

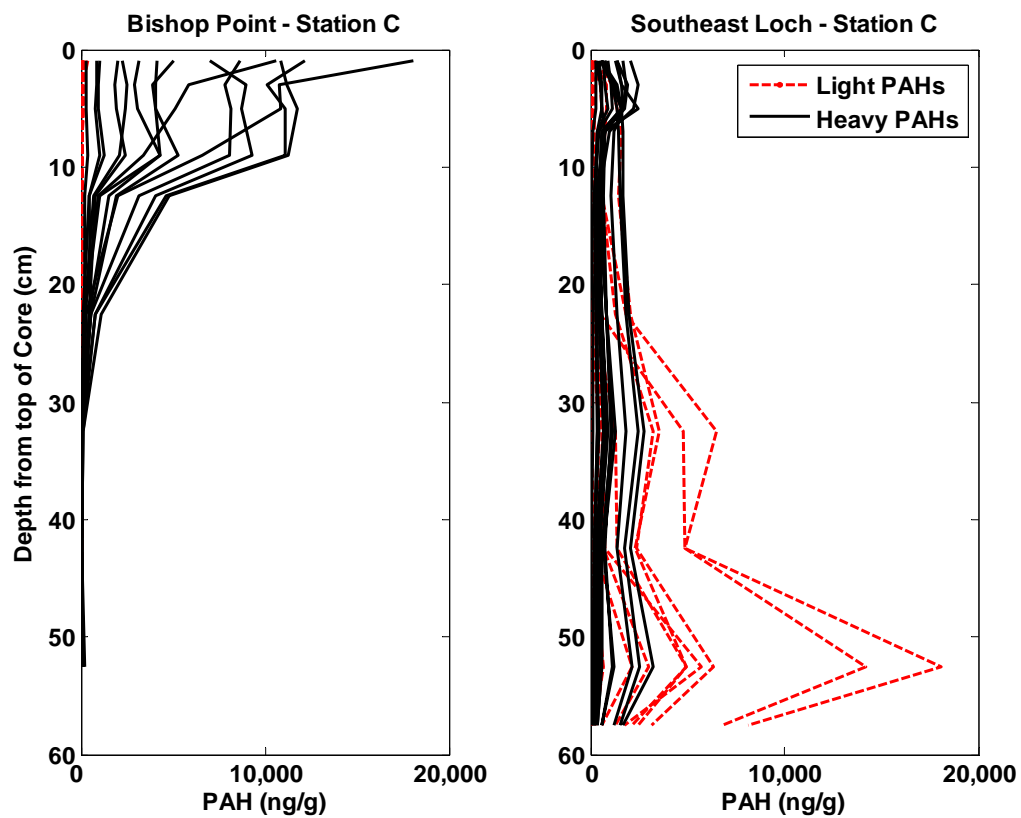


Figure 5-138. Selected PAH concentrations at stations BPC and SLC.

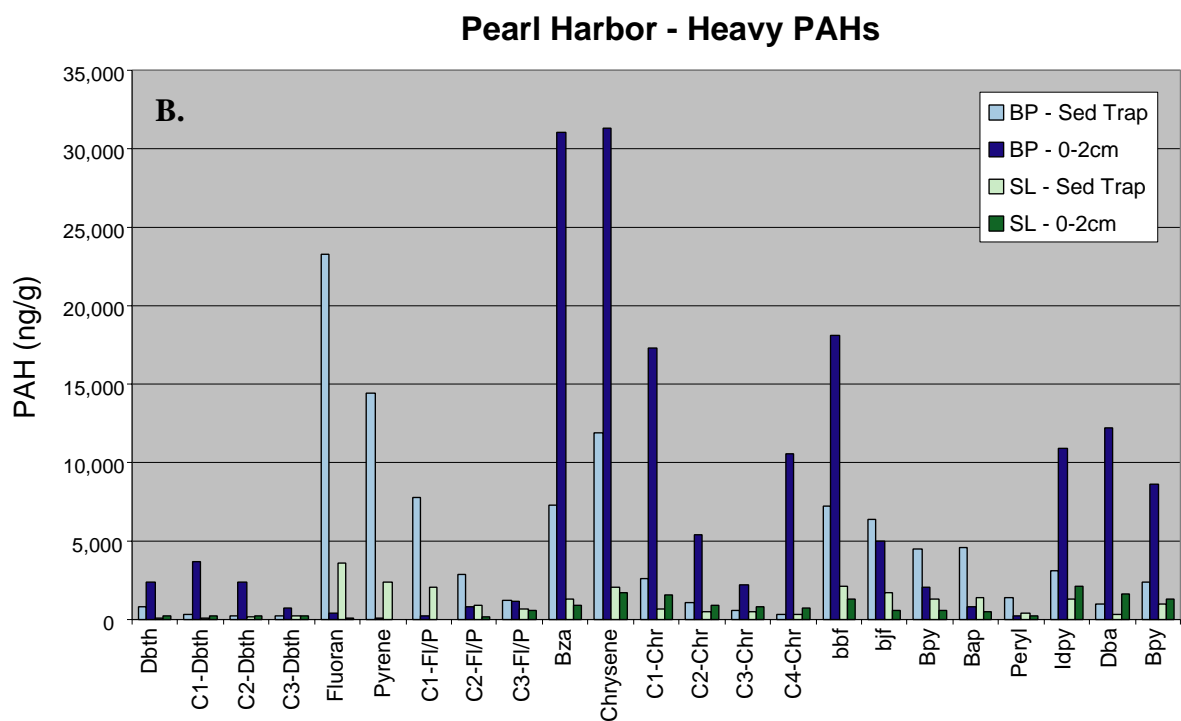
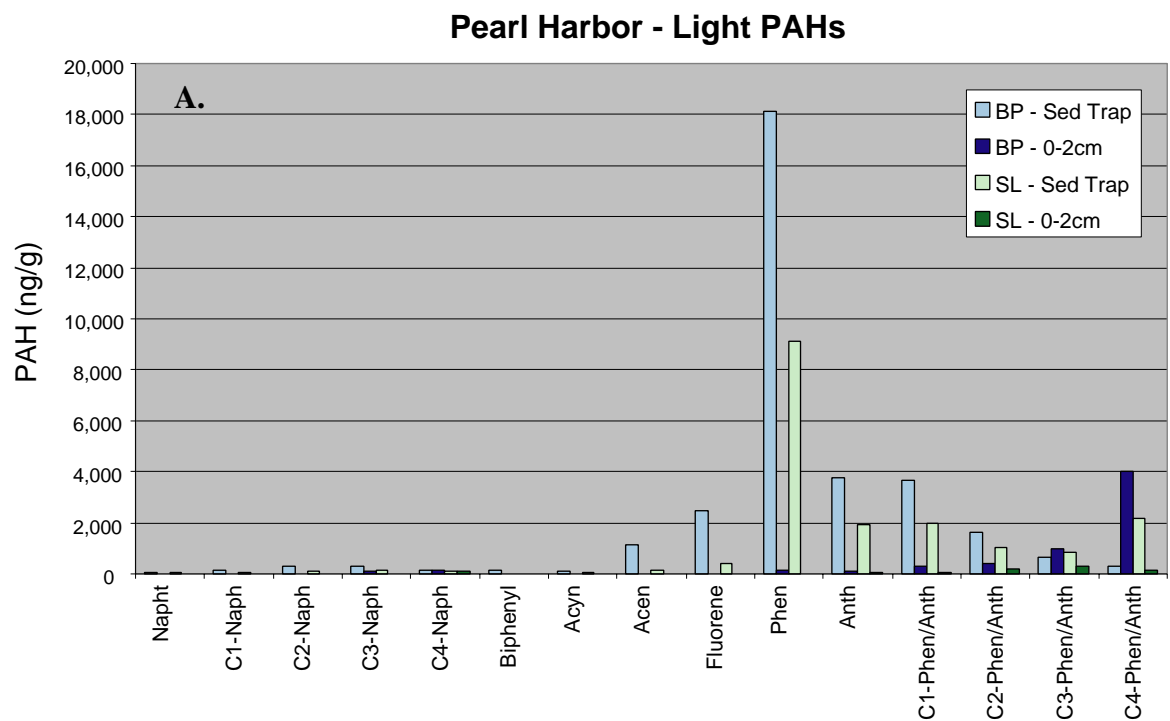


Figure 5-139. PAH concentrations from the sediment trap. PAH constituents are broken down by lighter (A) and heavier (B) molecular weights.

## Metals Measurements

At Bishop Point, copper, zinc, and lead show a sharp increase above ~30 cm (Figure 5-140). Concentrations are on the order of about 2 times higher at Southeast Loch and are relatively constant throughout the core. Metal concentrations were only slightly enriched in the sediment trap samples (Figure 5-141). Differences between traps and sediment cores are likely an effect of variations in grain size and organic carbon content.

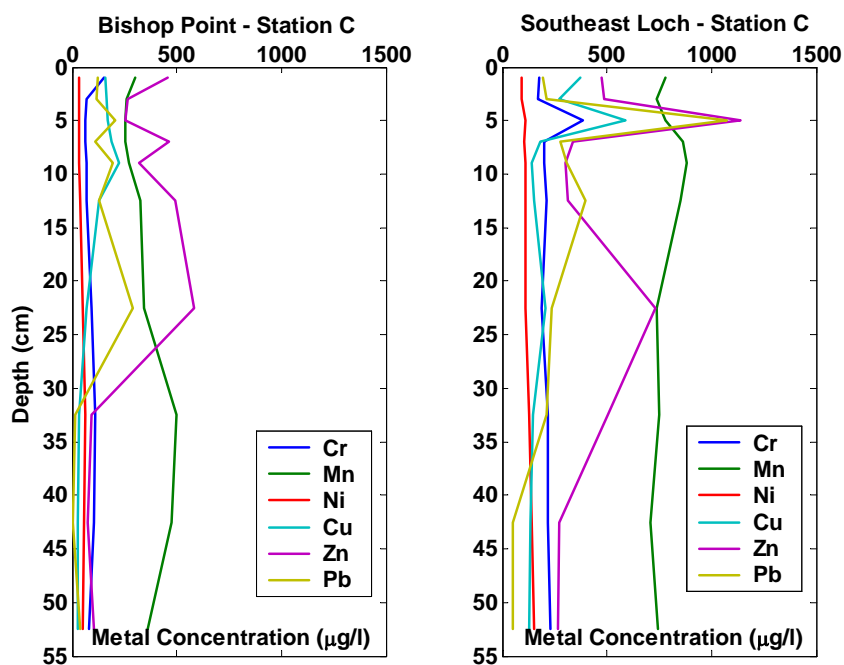


Figure 5-140. Metal concentrations for station BP-C and SL-C.

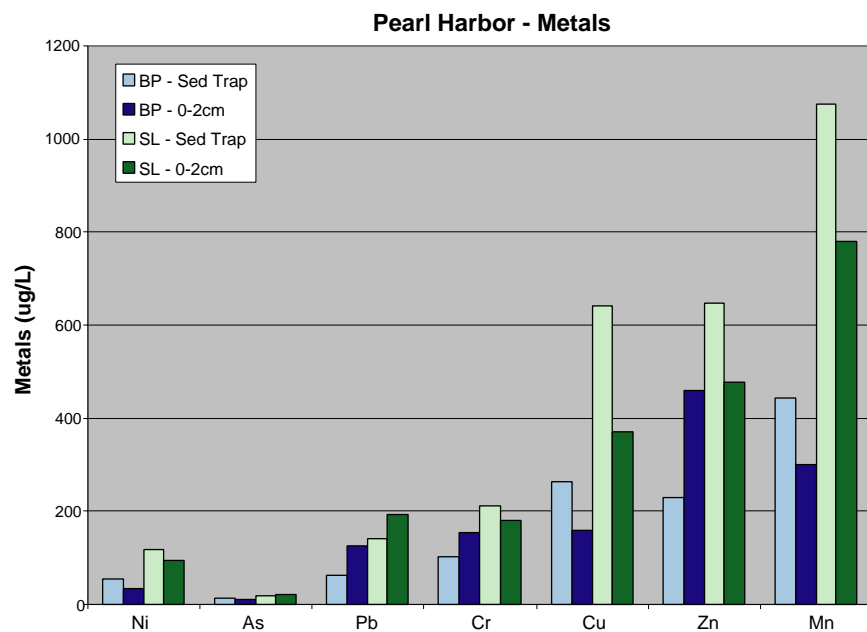


Figure 5-141. Metal concentrations of sediment trap samples compared to the uppermost core sample (0-2 cm).

## **6 Critical Assessment of Site II Successes and Failures**



In support of the critical assessment for Site II, we evaluated the following questions for each task component: 1) Did we successfully deploy the methods at the site? 2) Were contaminant flux parameters measurable? 3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? 4) What changes need to be made for the implementation of the measurement technology for future studies?

## **6.1 SPI MEASUREMENTS**

1) Did we successfully deploy the methods at the site? The sediment profile imaging (SPI) camera was successfully deployed as part of the Site II evaluations; as one of the first reconnaissance instruments deployed during the field trials, the SPI camera was used to characterize sediment and biological community conditions within the two sites.

2) Were contaminant flux parameters measurable? The SPI camera is not used to measure a flux, but to provide insight into the H value, site heterogeneity and overall context for other measurements. In that role, the camera images were available at the end of the field exercise and gave investigators immediate feedback on average biological mixing depths in the general area as well as at the two specific locations of interest. These immediate results for average biological mixing depth provided a key parameter for contaminant fluxes, and were critical for determining the depth to which samples were composited for the chemical analyses carried out during the subsequent coring operations.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Accurate measurements of actual bioturbation depths (H) were successfully achieved through subsequent detailed computer image analysis of selected slides and were used to calculate fluxes and indices as described in Section 3.

4) What changes need to be made for the implementation of the measurement technology for future studies? One particularly revealing aspect of this sediment profile imaging investigation came from the opportunity to do time-lapse imaging at one station in each of the areas surveyed; the results from these two deployments provided some tremendous insights into both the difference in bioturbation rates and associated processes occurring at these locations as well as the interpretation of different structures in the static “replicate images” taken as part of the regional survey. While the regular “regional survey” provided valuable information on the 3-dimensional spatial heterogeneity at the two sites, the time-lapse deployments provided insights for the first time on the fourth dimensional temporal heterogeneity -- the potential variation in reworking depths, reworking rates, and particle advection/ sediment transport that can occur at one location over a 24-hour period.

## **6.2 BFSD**

1) Did we successfully deploy the methods at the site? The standard BFSD was successfully deployed at both sites. Replicate fluxes were measured in each area.

2) Were contaminant flux parameters measurable? For several COPCs, flux rates were high enough to be clearly distinguishable from background fluxes. Replicate measurements provide an indication of flux variability in the field, and data are of sufficient quality to be applied to the pathway equations.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Measured flux rates from the BFS D were used successfully to directly calculate the combined chemical/biodiffusion flux ( $F_{DC} + F_{DB}$ ). As with Site I, we again had difficulty with the bioinhibited flux measurements, thus we were unable to measure the  $F_{DC}$  and  $F_{DB}$  terms separately. It appears that, even with site-specific data on oxygen demand, it is difficult to gage the time it will take for the chamber to become anoxic. This uncertainty stems from within-site variability, and differences between the dynamics of oxygen demand in the cores versus that in the BFS D.

4) What changes need to be made for the implementation of the measurement technology for future studies? To overcome this difficulty, it is recommended that future bioinhibited deployments be designed such that an initial set of samples is collected with the oxygen control system functioning, and that a secondary set then be collected only after the chamber has become fully anoxic.

### **6.3 ULTRASONIC SEEPAGE METER**

1) Did we successfully deploy the methods at the site? The ultrasonic seep meters were successfully deployed at both sites. Replicate discharge rates were measured in each area. Two strategies were attempted including (1) direct quantification of advective flux for CoPCs using the water sampling capability on the UltraSeep system, and (2) calculation of the advective flux for CoPCs using the discharge rates from the ultrasonic seepage meters combined with the composite porewater concentrations from the coring study. Due to some problems with the water sampling system of the prototype UltraSeep, we elected to base flux rates on method 2 which could be applied consistently at all stations.

2) Were contaminant flux parameters measurable? Contaminant flux parameters for the advective discharge included discharge rate, and CoPC concentrations below and within the sediment mixed layer. The discharge rate was successfully quantified using the ultrasonic seepage meters in both areas. For Bishop Point, conductivity transects and ultrasonic seepage meter data both indicate that the majority of the discharge is occurring away from the quay wall, presumably due to deflection of the groundwater flow around the sub-surface structure of the quay wall. Replicate measures at the same stations within the site gave similar results. For Southeast Loch, there was some evidence of biological irrigation in the seepage time-series at station SLB. Discharge rates at the three stations within the site were fairly comparable, with all stations showing positive discharge. Replicate measures at the same stations within the site gave similar results.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Ultrasonic seepage meters provided high-quality time-series data for groundwater discharge rates. The time-series data were used to calculate daily-mean discharge rates for each station, including replicate deployments. Together with composite porewater samples, these data provided a meaningful estimate of CoPC discharge for a range of contaminants.

4) What changes need to be made for the implementation of the measurement technology for future studies? Developmental changes need to be implemented for the UltraSeep to ensure that the water sampling system works properly. The advantage of direct sampling with the UltraSeep for future studies is that no assumptions are required regarding the reactivity of the CoPC with the sediment, which may significantly reduce advective fluxes, especially for hydrophobic contaminants. The advantage of the porewater approach is that the flux through the lower interface of the sediment mixed layer can also be estimated, while the UltraSeep measurement is limited to the flux through the top of the mixed layer.

#### **6.4 BIODEGRADATION RATES**

1) Did we successfully deploy the methods at the site? PAH mineralization assays were successfully completed for this demonstration at both sites. These measurements are most reliable when applied to the surface layer of intact cores, and when the assays are performed on-site with a minimal holding time. These requirements were achieved at the Pearl Harbor sites by utilizing a specialized collection system called the “multicore” which allows the retrieval of 10 – 15 cm deep undisturbed cores. The samples were analyzed immediately after collection at a field laboratory established on-site for the PRISM study.

2) Were contaminant flux parameters measurable? Mineralization rates were used to successfully estimate contaminant flux rates for PAHs via this pathway. The estimated fluxes rely on both the rates determined by the assay, and the estimated depth to which aerobic degradation is assumed to apply. There is considerable uncertainty as to the proper depth scale to apply in this instance. To bound this uncertainty, we applied two depth scales including (1) the depth to which oxygen penetration was observed using the microprofiling system, and (2) the biological mixing depth. Because these depths vary by up to two orders of magnitude, this range is quite wide. Down-core assays at both sites suggest that there is at least the potential for degradation below the observed oxygen penetration depth, likely resulting from the burrowing and irrigational activities of macrofauna at the sites.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Although there was a significant degree of variability in the replicate measurements, and there is still some uncertainty as to the applicable depth scale, the data were useful in bounding the potential range of this pathway index.

4) What changes need to be made for the implementation of the measurement technology for future studies? Factors that must be considered for the application of this data at this and future sites include the following. Only PAHs were being examined for this application, though other organic COPCs may be undergoing intrinsic recovery (e.g. TNT). This assay focuses on aerobic mineralization processes, and may thus underestimate potential down-core mineralization. It has been shown by a number of workers that degradation of some PAHs does occur in this region by strictly anaerobic processes. Total PAH mineralization rates are being extrapolated based upon spiked measurements of three individual PAHs. While the mineralization rates of these three PAHs have been observed to be strikingly similar at many sediment sites (by this methodology), the simplifying assumption that these spiked PAHs will reflect the behavior of the full PAH

mixture is still subject to some controversy. To be conservative, parallel estimates were made for just the PAHs measured as well as for total PAHs.

## **6.5 FLUME**

1) Did we successfully deploy the methods at the site? The VIMS Sea Carousel was successfully deployed at the two sites in Pearl Harbor.

2) Were contaminant flux parameters measurable? The primary parameters used to estimate the flux due to erosion include the erosion rate, the shear stress, and the bulk sediment CoPC concentration below and within the surface mixed layer. All of these parameters were successfully quantified for the Pearl Harbor sites, including the critical shear stress and erosion rate developed from the Sea Carousel.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Results from the Sea Carousel provided the basis for initial estimates of erosion potential at both sites in Pearl Harbor. Because of the logistical requirements and associated costs, we were not able to perform replicate measurements with the flume. Thus our understanding of the uncertainty associated with field variability of this method is limited for the Pearl Harbor study. However, shear strength measurements with the SPI system may be one means of assessing this variability on a broader scale.

4) What changes need to be made for the implementation of the measurement technology for future studies? The Sea Carousel appears to be a well-refined method that can be applied at sites in the future with little modification. The biggest question for the method is whether or not meaningful measurements can be obtained by ex-situ methods such as the SedFlume technique, which are less expensive and can be applied at more stations. The main advantages of the Sea Carousel appear to be that uncertainty is reduced by (1) eliminating artifacts associated with collection and transport of samples from the site, (2) integrating the critical shear stress and erosion rate estimates over a relatively large area, thus minimizing effects of localized heterogeneity, (3) minimization of edge effects that are often problematic in laboratory flumes using small diameter cores, and (4) allowing for relatively high shear stresses as might be observed in harbor settings associated with tidal currents, ships and storms.

## **6.6 LISST IN SUPPORT OF RESUSPENSION MEASUREMENTS**

Due to funding constraints and the qualitative results from Site I, the LISST was not employed for Site II analysis. Only traditional, quantitative grain-size analyses were conducted at Site II.

## **6.7 AGE-DATING/SEDIMENT TRAPS**

1) Did we successfully deploy the methods at the site? Age-dating cores were successfully collected at both Pearl Harbor sites using a gravity core for  $^{210}\text{Pb}$ , and the multicore for  $^7\text{Be}$  and  $^{137}\text{Cs}$ . Cores were successfully sub-sampled on site, and analyzed in the laboratory for all target tracers. Sediment traps were also successfully deployed and retrieved from both sites, and samples were processed to determine trap accumulation rates and CoPC concentrations in the accumulated sediment.

2) Were contaminant flux parameters measurable? The primary parameters required to estimate the sedimentation flux include the sedimentation rate, and the concentration of CoPCs in the sediment beneath and within the mixed layer, as well as the concentration in the deposited material. Sedimentation rates were successfully measured by  $^{210}\text{Pb}$  and sediment traps at the BP site, and by sediment traps at the SL site. The tracer  $^{137}\text{Cs}$  was not useful in confirmation the sedimentation rates due to potential disturbance or removal activities at the sites. The tracer  $^7\text{Be}$  which is used to estimate short-term deposition was not detected at either site. In addition, recent dredging activity at the SL site confounded the estimate of sedimentation rates by  $^{210}\text{Pb}$  at the SL site.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Sedimentation rates and deposition concentrations were of sufficient quality to estimate flux rates for this pathway. Due to cost constraints, no replication was included for the age-dated coring, thus the spatial and field variability associated with these results is unknown. In addition, the age-dating results may have been confounded by disturbance and removal activities at the sites, as they are at many study sites. For the sediment traps, replicate measurements yielded similar results. However, there is uncertainty as to whether the material in the traps represents the deposition of new material, or simply the re-deposition of locally resuspended material.

4) What changes need to be made for the implementation of the measurement technology for future studies? The largest implementation barrier for natural tracer methods appears to be the confounding effects of disturbance and dredging. These processes are fundamental to active DoD harbor settings. Even at sites that are likely to have significant deposition, these methods may not be reliable if the down-core profiles have been disturbed. Sediment traps provide a short-term method for assessing sedimentation rates. However traps can be confounded by the same types of localized disturbance processes that hamper tracers, leading to potential over-estimates of the sedimentation rates. These problems are not unique to the PRISM program, but rather represent limitations of these standard methodologies. Thus, these limitations must be borne in mind during data interpretation.

## **6.8 POREWATER AND SOLID PHASE CORE PROFILING AND MICROPROFILING**

1) Did we successfully deploy the methods at the site? Porewater and solid phase concentrations of CoPCs and other important biogeochemical species were successfully measured in intact cores from each of the two sites in Pearl Harbor.  $\text{O}_2$ , pH and  $\text{H}_2\text{S}$  microgradients were successfully measured in intact cores from both sites.

2) Were contaminant flux parameters measurable? Core profiling results were used to successfully estimate flux parameters for a number of processes. Porewater CoPC concentrations below and within the sediment mixed layer were used as parameters in the advective flux calculation. Solid phase CoPC concentrations were used as parameters in the erosion and deposition flux calculations. Oxygen penetration depths were used as a parameter in the biodegradation flux calculation. In addition, profiling measurements were used to interpret the results for many of the observed processes at the site.

3) Were data from field methods of sufficient quality that they could be meaningfully applied to transport indices? Profiling results were generally of high quality and provided significant support in the estimation of transport indices. Replicate measurements were obtained at both sites, providing a means of quantifying field and spatial variability associated with the pathways estimated from these parameters.

4) What changes need to be made for the implementation of the measurement technology for future studies? Porewater and solid phase core profiling is a fairly routine process that does not require significant refinement. The main difficulty is in obtaining undisturbed cores, and carefully processing them so as not to disturb the profiles that are being quantified. This goal was achieved in this study using a relatively new multicore system that reliably collects four undisturbed cores with each drop. In addition, it is generally necessary to process, and in some cases (microprofiling) analyze the cores on-site so as to minimize disturbance that might be associated with transport to the laboratory. On-site processing and analysis adds a higher level of cost and complexity to the quantification of these parameters, but results in a significant improvement in data quality.

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## **7 Calculations of Fluxes for PRISM Pathways**



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Pathway and flux analysis for Site II contained the following elements: 1) Evaluation of conceptual model, 2) evaluation of available site data, 3) field design, 4) field deployment and synthesis of field data immediately available (screening and SPI results), 5) analytical results, 6) process-specific analysis (evaluation of BFSD, flume, etc. on their own), 8) synthesis of results in terms of the field site, and 9) evaluation of results in terms of management/contaminant behavior insight. Here we present the process-specific analyses, along with analysis of the variability associated with each flux estimate.

## 7.1 ADVECTIVE FLUX

Advective flux rates were calculated based on two measurement data sets. Specific discharge rates ( $w$ ) were determined from multiple deployments of ultrasonic seepage meters within each site. Porewater concentrations were measured in the laboratory from composite samples collected at the same stations where the seepage meters were deployed. Porewater concentrations were determined for the sediments below the mixed layer ( $c_{H-}$ ), the mixed layer ( $c_H$ ), and the overlying surface water ( $c_O$ ). The advective flux for a given chemical is then estimated as

$$F_A = w(c_{H-} - c_H) \quad w \geq 0$$

$$F_A = w(c_H - c_O) \quad w < 0$$

Advective fluxes were calculated for each station at each site based on the equations above. The site-mean flux was then calculated as the average of the stations fluxes within the site. Results for metals and PAHs are shown in Table 7-1 and Table 7-2. Note that advective flux rates are based on 24-hour mean discharge rates at each station and do not account for short-term variations associated with tides. Tidal pumping can act to both enhance discharge, and to attenuate porewater concentrations.

### Variability of the measurement

Variability for advective discharge was quantified based on (1) variations in the specific discharge time-series record at each station, (2) variation in specific discharge rates between replicate deployments at the same station, (3) variation in specific discharge rates, porewater concentrations, and flux rates between stations within the same site, and (4) variation in specific discharge rates, porewater concentrations, and flux rates across the two sites.

Variability in the specific discharge time-series at each station is influenced by tidal and upland variations in hydraulic gradients, as well as potential variations in biological irrigation. For Bishop Point, variations associated with tidal forcing appeared to be fairly weak at all stations, with typical ranges of 2-3 cm/day. Some shorter term variability was observed at BPA and BPC that may have been related to bioirrigation. At Southeast Loch, tidal variations of 2-3 cm/day were also observed in the specific discharge, and bioirrigation appeared to be strong at SLB with fluctuations of 5-6 cm/day.

Variability between replicate deployments at the same station reflects the combined effects of small scale heterogeneity and measurement error. Replicate measurements generally showed similar trends, but with somewhat different magnitudes of specific discharge. For example, at

station BPB, both replicates showed low discharge rates, but the mean specific discharge rate for replicate 1 was slightly positive, while the rate for replicate 2 was slightly negative. At BPC and SLC, both replicates showed relatively high specific discharge rates, but in both cases, the discharge rate for replicate 1 was somewhat higher than that for replicate 2. In general, replicate measures of the mean specific discharge rate were comparable within a factor of 2.

Within site variability of measured advective flux rates was influenced by variations in both specific discharge rates and porewater concentrations. For example, at Bishop Point, an increasing gradient of discharge was observed with distance from the quay wall. Thus there was a higher discharge potential for site BPC compared to sites BPA and BPB. For station BPC, the porewater gradient for most metals was increasing with depth, thus strong positive advective fluxes were estimated, whereas for PAHs the porewater gradient was generally decreasing with depth, so strong negative advective fluxes were estimated. For Southeast Loch, specific discharge rates were fairly consistent among stations. However, the strong increase in porewater PAH concentration with depth at station SLC generated large positive flux rates for this station. These types of variations led to within-site relative standard deviations ranging from about 50-200% for most chemical fluxes at both Bishop Point and Southeast Loch.

Variations in advective fluxes across sites are associated with differences in contamination levels, groundwater gradients, physical characteristics of the sediment, geochemical conditions, and biological communities. In general, it appears that advective discharge of groundwater is generally higher and more spatially consistent at Southeast Loch compared to Bishop Point. However, for metals, advective discharge was generally higher and more consistently positive at Bishop Point due to the stronger porewater gradients present there (Figure 7-1). Arsenic, cadmium, lead, nickel and zinc all had positive advective discharge at Bishop Point. For PAHs, the strong porewater gradient at SLC led to a dominant positive site-average advective flux for Southeast Loch compared to Bishop Point where the porewater gradient was weak and generally decreasing with depth leading to negative advective flux rates (Figure 7-2). Thus comparative advective contaminant fluxes for the two sites varied considerably due to differences in the interaction of contaminant gradients in the porewater with the magnitude and direction of the specific discharge.

	BPA	BPB	BPC	Mean	Stdev.
Bishop Point	Arsenic	-4.6	2.5	80.0	26.0
	Copper	-1.5	3.6	-40.8	-12.9
	Cadmium	-0.23	-0.02	2.01	0.59
	Lead	-0.74	0.05	10.12	3.14
	Nickel	48	9	1836	631
	Manganese	-944	237	-8154	-2954
	Silver	-0.034	-0.001	ND	-0.012
	Zinc	-114	24	1034	315
	SLA	SLB	SLC	Mean	Stdev.
Southeast Loch	Arsenic	-15.3	15.8	-89.1	-29.5
	Copper	-9.9	-6.7	-17.4	-11.3
	Cadmium	-1.23	0.44	0.63	-0.05
	Lead	3.77	1.21	6.28	3.76
	Nickel	-15	-92	1476	456
	Manganese	-4779	-13508	-28017	-15435
	Silver	ND	ND	-0.146	-0.049
	Zinc	-118	-24	-238	-127

Table 7-1. Advective flux rates for metals at Bishop Point and Southeast Loch including individual station fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .

		BPA	BPB	BPC	Mean	Stdev.
Bishop Point	Naphthalene	-29	76	-2487	-813	1450
	Acenaphthylene	-18	9	-381	-130	218
	Acenaphthene	-600	597	-14169	-4724	8201
	Fluorene	-332	422	-8267	-2726	4813
	Phenanthrene	-1487	1447	-20804	-6948	12089
	Anthracene	-303	198	-4325	-1477	2480
	Fluoranthene	-2266	1039	ND	-7660	12315
	Pyrene	-445	918	-20925	-6817	12237
	Benzo(a)anthracene	-491	248	-3926	-1390	2228
	Chrysene	-841	432	-6964	-2458	3954
	Benzo(b)fluoranthene	-162	680	-485	11	602
	Benzo(j/k)fluoranthene	-143	536	585	326	407
	Benzo(e)pyrene	-128	464	-1879	-514	1219
	Benzo(a)pyrene	-61	510	48	166	303
	Perylene	-143	123	-1521	-514	882
	Indeno(1,2,3-c,d)pyrene	-332	326	-890	-299	609
	Dibenz(a,h)anthracene	-91	74	-365	-127	222
	Benzo(g,h,i)perylene	-181	218	-724	-229	473
		SLA	SLB	SLC	Mean	Stdev.
Southeast Loch	Naphthalene	32	-12	-102637	-34206	59263
	Acenaphthylene	-11	-30	1966	642	1147
	Acenaphthene	-577	-3040	157150	51178	91783
	Fluorene	-649	-505	87487	28778	50844
	Phenanthrene	-5818	-1756	123352	38592	73432
	Anthracene	-952	-1196	54177	17343	31899
	Fluoranthene	-6605	-20458	694817	222584	409024
	Pyrene	-8977	-23911	1054336	340483	618260
	Benzo(a)anthracene	-787	-6261	314999	102650	183920
	Chrysene	-868	-6411	340401	111041	198651
	Benzo(b)fluoranthene	-718	-3276	262296	86101	152595
	Benzo(j/k)fluoranthene	-1127	-2814	208917	68325	121759
	Benzo(e)pyrene	-940	-3302	236386	77381	137707
	Benzo(a)pyrene	-1238	-2790	169012	54994	98745
	Perylene	-253	-1068	96602	31760	56156
	Indeno(1,2,3-c,d)pyrene	-224	-882	99729	32875	57899
	Dibenz(a,h)anthracene	-16	-290	31339	10344	18182
	Benzo(g,h,i)perylene	-102	-948	101140	33363	58698

Table 7-2. Advective flux rates for PAHs at Bishop Point and Southeast Loch including individual station fluxes, and site-average fluxes. All values are ng/m<sup>2</sup>/d.

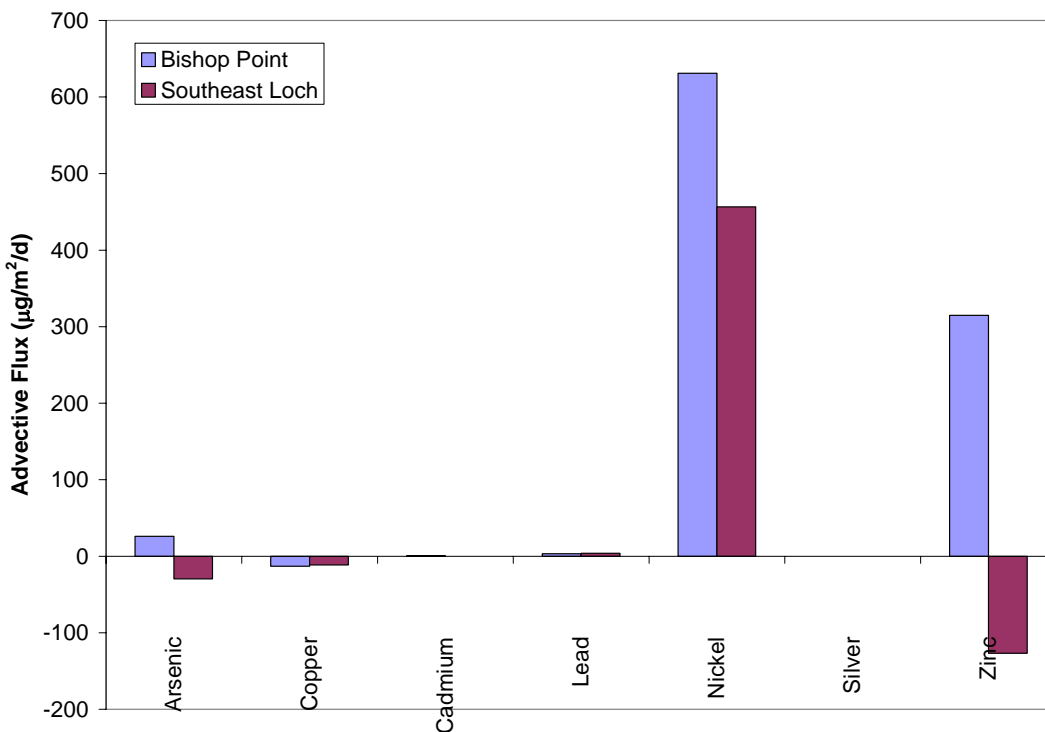


Figure 7-1. Comparison of site-average advective metal fluxes for the Bishop Point and Southeast Loch sites.

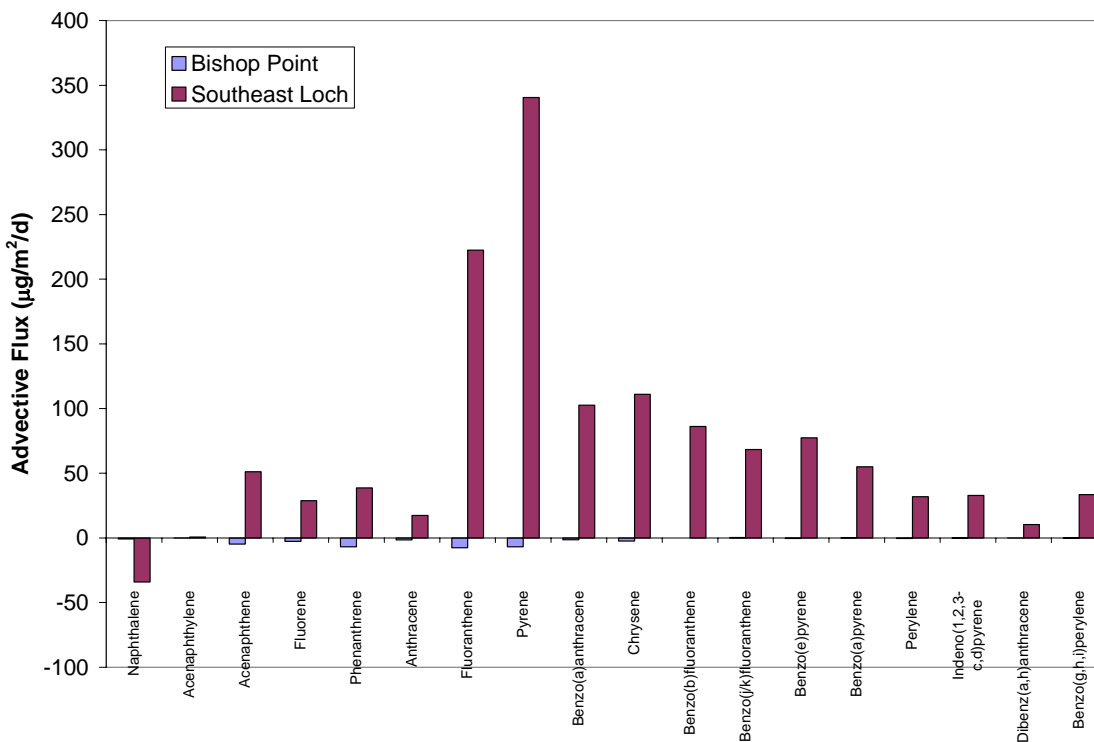


Figure 7-2. Comparison of site-average advective PAH fluxes for the Bishop Point and Southeast Loch sites.

## 7.2 DIFFUSIVE/BIOIRRIGATION FLUX

Fluxes associated with molecular and biologically mediated diffusive pathways were calculated directly from the time-series concentrations measured in the BFS. Attempts to separate the biological component of the flux by limiting oxygen supply to the BFS chamber were unsuccessful. Thus the reported flux rates represent the combined effect of all diffusive processes. Because there is no flow path for water through the BFS, the fluxes do not include advection. The diffusive flux was calculated from the time series data as

$$F_D = F_{DC} + F_{DB} = \frac{V}{A} \frac{dc}{dt}$$

Here  $V$  is the chamber volume, and  $A$  is the surface area of the sediment enclosed by the chamber. Diffusive fluxes were calculated for each station at each site based on the equations above. The site-mean flux was then calculated as the average of the stations fluxes within the site. Results for metals and PAHs are shown in Table 7-3 and Table 7-4.

### Variability of the measurement

Variability for advective discharge was quantified based on (1) variation in flux rates between stations within the same site, and (2) variation in flux rates across the two sites.

Variability in metal and PAH fluxes was quantified on three distinct scales in this study including (1) variability in individual measurements, (2) variability within a site (scale 20-100 m), and (3) variability between sites (scale 5 km). Variability within an individual flux measurement is quantified based on the variance of the slope of the concentration with time. The variability in the slope may arise from a number of factors including actual non-linearity of the measured process, sample contamination, and analytical variability. For the BFS, assessment of this variability is evaluated based on comparison to blank chamber runs (runs with a Teflon panel in place of sediment). Based on a statistical comparison of the deployment data versus the blank, an assessment is made as to whether the flux is “detectable”. This simply means that a flux was detected by the instrument that can be distinguished from a flux when no sediment is present. This does not necessarily imply that the flux is significant from a transport or ecological perspective. By the same token, failure to detect a flux that is distinguished from the blank does not necessarily mean that the flux is insignificant, rather that with the BFS technology, we are simply not able to determine a flux rate that is quantifiable in comparison to the blank. This is parallel to, for example, the measurement of a water concentration. If the concentration is detectable, we can quantify the value, but this does not infer that it exceeds an effects threshold. Similarly if we cannot detect it, but the effects threshold is below our detection limit, we cannot rule out a potential effect. For this reason, it is important to know whether fluxes were detectable when interpreting the data here, but we continue to use the entire data set for the general analysis so that perspective can be gained on the relative importance of fluxes within the context of PRISM. In general, we found that fluxes for the listed metal and PAH constituents were detectable in the majority of the deployments. The primary exceptions included Ag for the

metals, and Acenaphthene and Fluorene for the PAHs. In addition, For several PAHs, chemical concentrations were below detection, so no flux could be calculated.

Within site variability of measured diffusive flux rates is generally influenced by spatial heterogeneity and localized variations in contamination, porewater gradients, and geochemical conditions. Within site variability was evaluated on the basis of three deployments at stations separated by tens of meters. In general, these results indicate a fairly consistent pattern of fluxes within each site. For example, arsenic, lead and zinc all showed consistently positive fluxes within the Bishop Point site, with flux rates varying within a factor of 2 (Figure 7-3). Similar patterns were observed for copper, nickel and zinc at the Southeat Loch site. PAH fluxes at both sites showed somewhat higher within site variability (Figure 7-4).

Variations in diffusive fluxes across sites are associated with large-scale differences in contamination levels, porewater gradients, physical characteristics of the sediment, geochemical conditions, and biological communities. Thus comparison across sites provides insight into how well our tools can distinguish differences as we move from one environment to another. Comparison of metal fluxes between the BP and SL areas showed a general similarity, with a few exceptions (Figure 7-5). In general, site mean metal fluxes were comparable for As, Cu and Zn. The BP site had consistently higher fluxes of Pb, while the SL site had consistently higher fluxes of Cd and Ni. Site mean fluxes for Ag were difficult to compare due to the lack of detectable levels at several stations. Direct comparison of the two areas indicates statistical differences for Cd ( $p < 0.05$ ), Pb ( $p < 0.04$ ), and Ni ( $p < 0.03$ ). Comparison of PAH fluxes between the BP and SL areas also showed some distinctive patterns. In general, site-average PAH fluxes were higher at BP compared to SL (Figure 7-6). Only Pyrene had a higher mean fluxes at SL. Site mean fluxes for Acenaphthene, Fluorene and Phenanthrene were negative at both sites. Direct comparison of the two areas indicates statistical differences for Anthracene ( $p < 0.12$ ), and Fluoranthene ( $p < 0.12$ ).



		BPA	BPB	BPC	Mean	Stdev.
Bishop Point	Arsenic	48.4	23	27	32.8	-13.7
	Copper	9.9	-71	140	26.3	-106
	Cadmium	-1.7	1.3	0.26	-0.05	-1.52
	Lead	38	17	42	32.3	-13.4
	Nickel	3.9	59	11	24.6	-30.0
	Manganese	5683	428	237	2116	-3091
	Silver	2.8	0	1.9	2.35	-0.64
	Zinc	186	374	332	297	-98.7
		SLA	SLB	SLC	Mean	Stdev.
Southeast Loch	Arsenic	80	-34	18	21.3	-57.1
	Copper	8.3	46	6.2	20.2	-22.4
	Cadmium	2.3	2.5	5.7	3.50	-1.91
	Lead	-11	8.6	11	2.87	-12.1
	Nickel	123	46	121	96.7	-43.9
	Manganese	798	2171	766	1245	-802
	Silver	0	-1.3	0	-1.3	0
	Zinc	179	389	499	356	-163

Table 7-3. Diffusive flux rates for metals at Bishop Point and Southeast Loch including individual station fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .

		BPA	BPB	BPC	Mean	Stdev.
Bishop Point	Naphthalene	ND	711	-218	247	-657
	Acenaphthene	ND	-1388	-317	-853	-757
	Acenaphthylene	ND	107	-104	2	-149
	Fluorene	ND	-359	271	-44	-445
	Phenanthrene	ND	-640	488	-76	-798
	Anthracene	ND	764	284	524	-339
	Fluoranthene	ND	2750	603	1677	-1518
	Pyrene	ND	2192	1645	1919	-387
	Benzo(a)anthracene	ND	ND	ND	NA	NA
	Chrysene	ND	ND	ND	NA	NA
	Benzo(b)fluoranthene	ND	ND	ND	NA	NA
	Benzo(j/k)fluoranthene	ND	ND	ND	NA	NA
	Benzo(e)pyrene	ND	ND	ND	NA	NA
	Benzo(a)pyrene	ND	ND	ND	NA	NA
	Perylene	ND	ND	ND	NA	NA
	Indeno(1,2,3-c,d)pyrene	ND	ND	ND	NA	NA
	Dibenz(a,h)anthracene	ND	ND	ND	NA	NA
	Benzo(g,h,i)perylene	ND	ND	ND	NA	NA
		SLA	SLB	SLC	Mean	Stdev.
Southeast Loch	Naphthalene	-564	4	26	-178	-334
	Acenaphthene	-1392	ND	-729	-1061	-469
	Acenaphthylene	-130	-55	-48	-78	-45
	Fluorene	-704	ND	-118	-411	-414
	Phenanthrene	-1040	-167	192	-338	-634
	Anthracene	-176	104	-46	-39	-140
	Fluoranthene	-1492	-1045	-149	-895	-684
	Pyrene	4302	-1020	4666	2649	-3183
	Benzo(a)anthracene	ND	ND	ND	NA	NA
	Chrysene	ND	ND	ND	NA	NA
	Benzo(b)fluoranthene	ND	ND	ND	NA	NA
	Benzo(j/k)fluoranthene	ND	ND	ND	NA	NA
	Benzo(e)pyrene	ND	ND	ND	NA	NA
	Benzo(a)pyrene	ND	ND	ND	NA	NA
	Perylene	ND	ND	ND	NA	NA
	Indeno(1,2,3-c,d)pyrene	ND	ND	ND	NA	NA
	Dibenz(a,h)anthracene	ND	ND	ND	NA	NA
	Benzo(g,h,i)perylene	ND	ND	ND	NA	NA

Table 7-4. Diffusive flux rates for PAHs at Bishop Point and Southeast Loch including individual station fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .

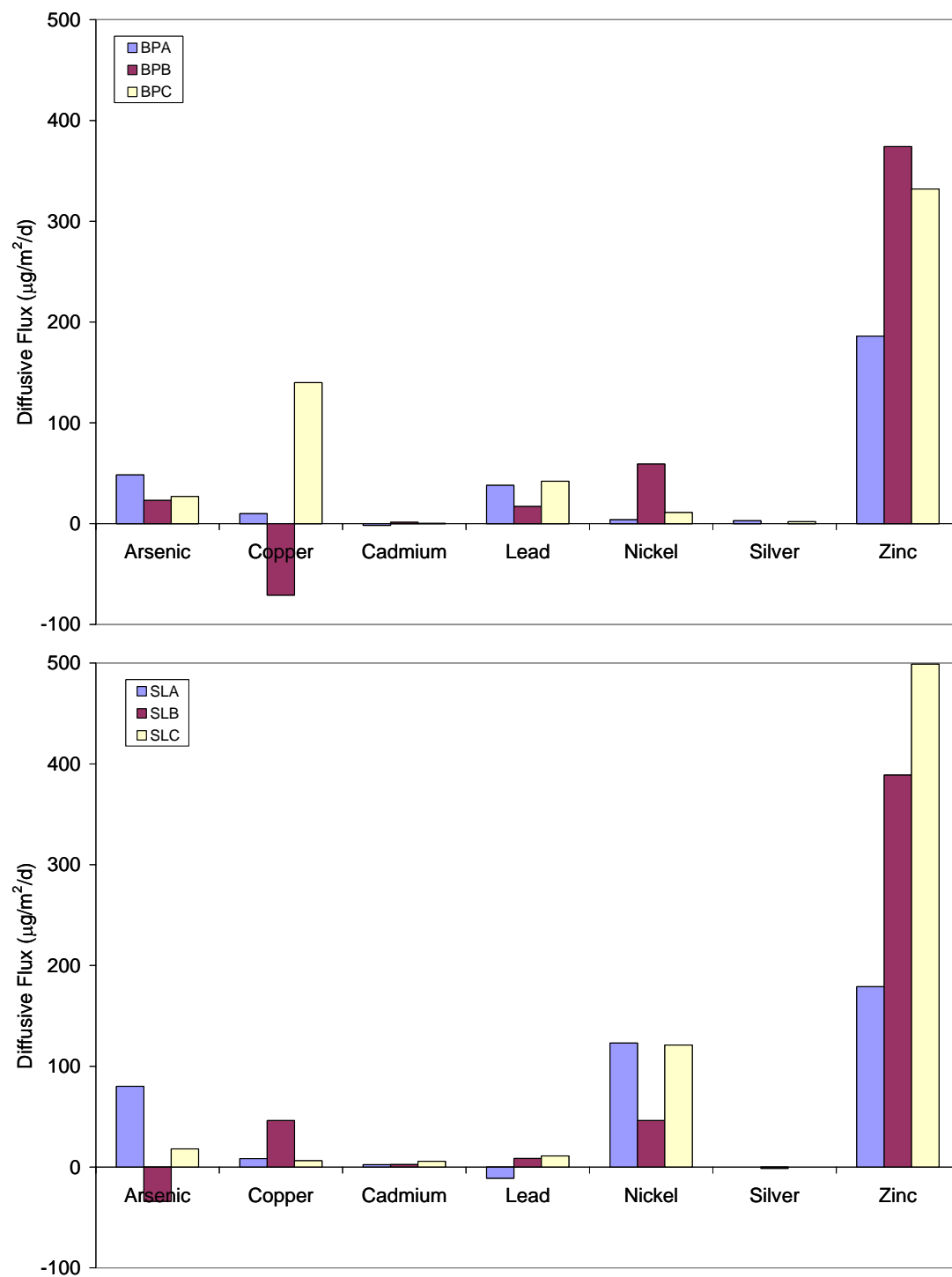


Figure 7-3. Within-site variation of diffusive metal fluxes for the Bishop Point (above) and Southeast Loch (below) sites.

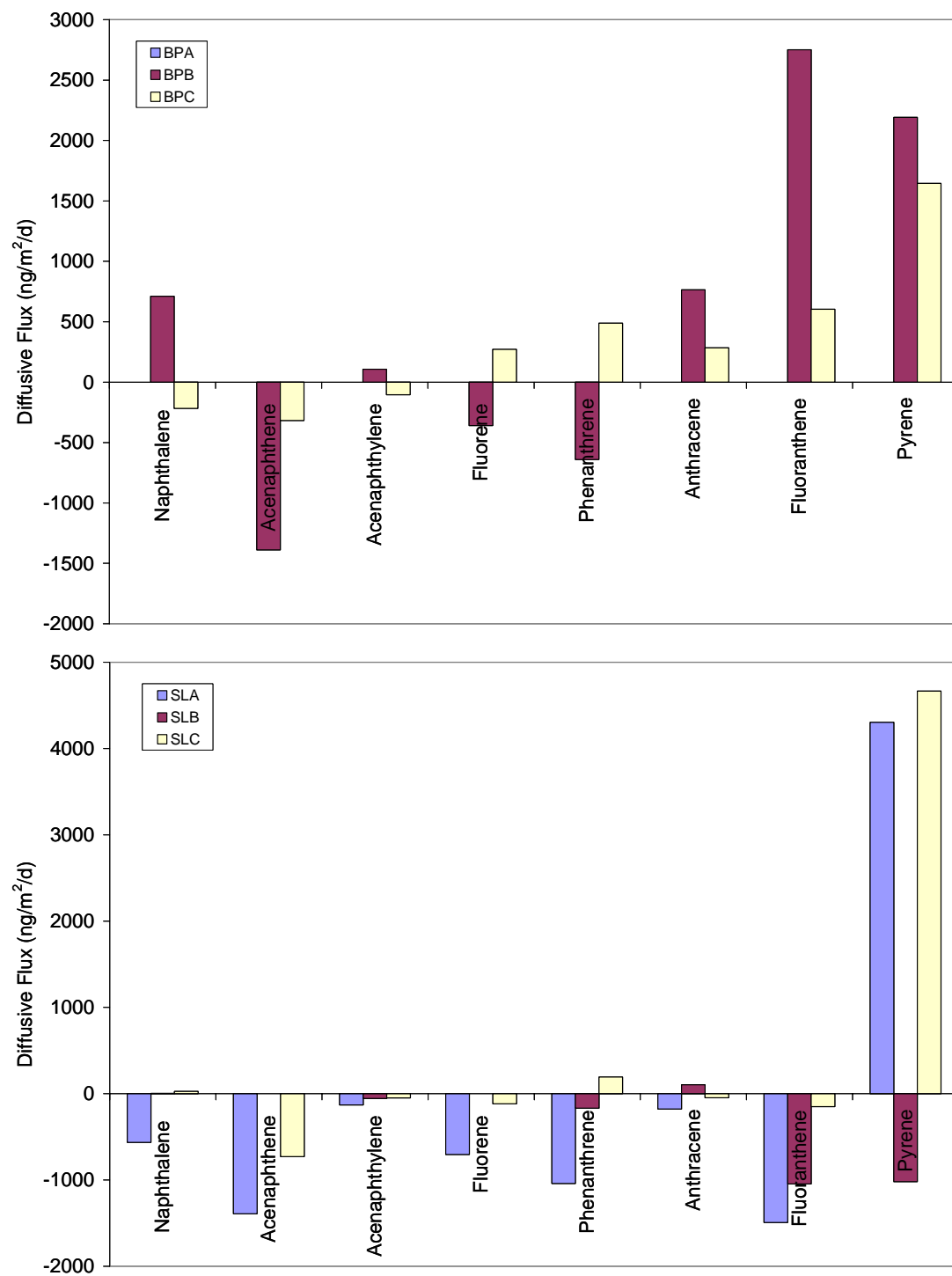


Figure 7-4. Within-site variation of diffusive PAH fluxes for the Bishop Point (above) and Southeast Loch (below) sites.

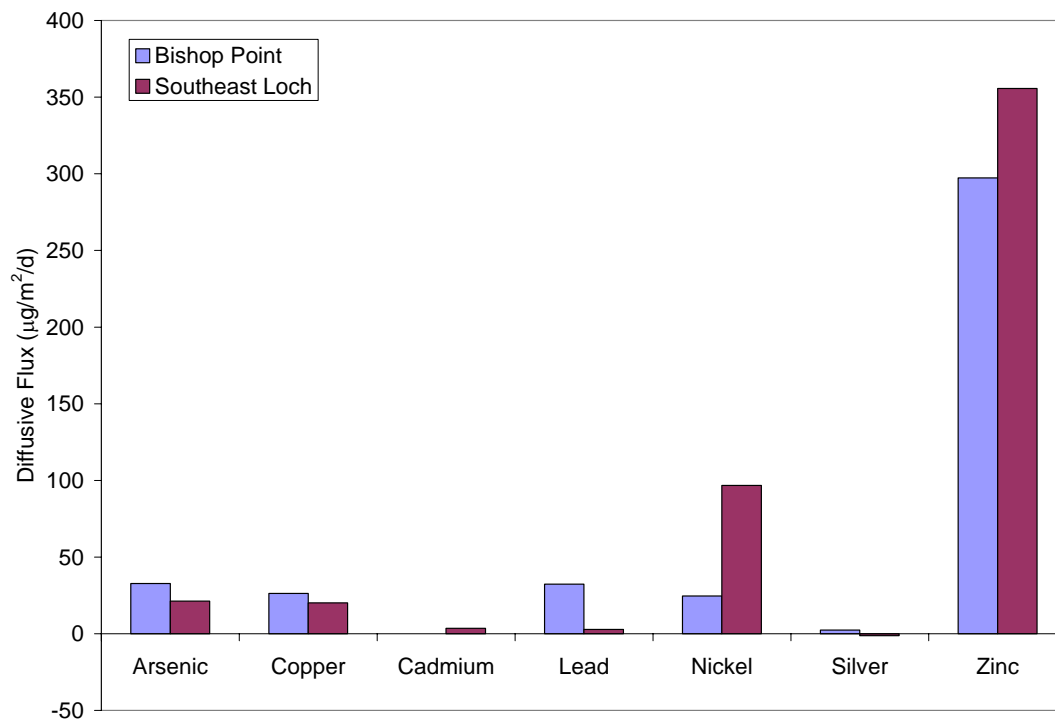


Figure 7-5. Comparison of site-average diffusive metal fluxes for the Bishop Point and Southeast Loch sites.

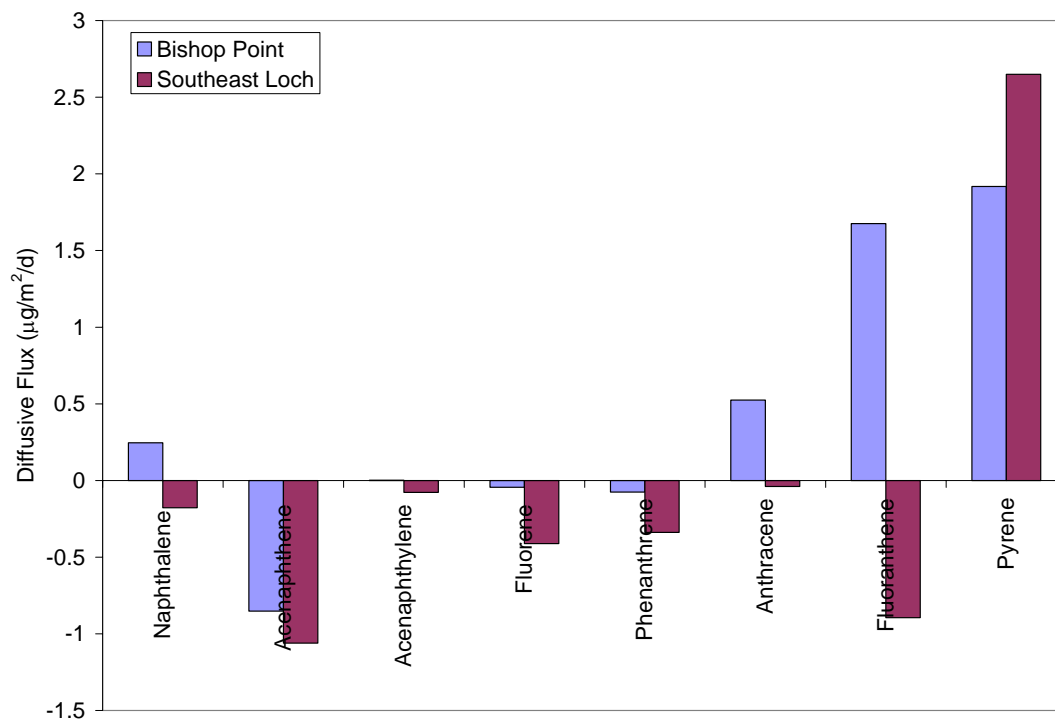


Figure 7-6. Comparison of site-average diffusive PAH fluxes for the Bishop Point and Southeast Loch sites.

### 7.3 FLUX BY SEDIMENTATION

Fluxes associated with sedimentation were calculated from trap and core derived sedimentation rates ( $S$ ), and trap ( $c_s$ ) and bed ( $c_B$ ) contaminant concentrations. When new sediment deposits on the bed, the contaminant load of the mixed layer can be changed in several ways. If the depositing sediment is cleaner than the bed, then the sedimentation will reduce the concentration in the mixed layer. Alternatively, if the depositing sediment is more contaminated than the bed, then the sedimentation will increase the concentration in the mixed layer. The sedimentation flux was calculated from the sediment trap data as

$$F_s = S(c_B - c_s)$$

Sedimentation fluxes were calculated for each station at each site based on the equations above. The site-mean flux was then calculated as the average of the stations fluxes within the site. Results for metals and PAHs are shown in Table 7-5 and Table 7-6. Sedimentation rates determined by age dating were found to be unreliable for Southeast Loch due to perturbation of the historical record by recent dredging activities. Thus, to be consistent, trap measurements were used for both sites. It should be noted that resuspension effects can lead to a high bias in sedimentation rates from trap. However, in the context of contaminant deposition, if the material is resuspended sediment, the deposition rate will be negligible because the depositing sediment and bed sediment concentrations will be approximately the same ( $c_s \approx c_B$ ).

#### Variability of the measurement

Variability for sedimentation fluxes was quantified based on (1) variation in sedimentation rates determined by two methods (cores and traps), (2) variation in sedimentation rates, bed concentrations, and trap concentrations between replicate deployments at the same station, and (3) variation in sedimentation flux rates across the two sites.

Methodological variability in sedimentation rates was assessed based on comparison of results for age-dated cores with results from sediment traps. In general, sedimentation rates based on age dating with  $Pb^{210}$  provide a long-term (~10-100 year) average for the site, while sediment traps provide a short-term average (length of deployment 10-100 days). Isotope profiles at Southeast Loch showed a classical decay with depth, however the estimated sedimentation rate was very low, and the dates did not correspond with expectations regarding contamination profiles. It was determined that the area had been recently dredged, and that the profile probably reflected a dredging residual in the surface layer that had been recently mixed with the older sediments that were exposed by dredging. Thus there was no way of resolving a comparative rate for sedimentation. The sedimentation rate measured by the traps was consistent with previously measured rates in coastal and estuarine settings. For Bishop Point, the age-dated cores predicted a sedimentation rate somewhat lower than that measured by the traps. The higher rates measured in the traps could reflect resuspension, or short-term inputs associated with stormwater runoff.

Variability between replicate deployments at the same station reflects the combined effects of small scale heterogeneity and measurement error. Replicate measurements generally showed similar trends, but with somewhat different magnitudes of sedimentation rate. For example, at

Bishop Point, replicates sedimentation rate measurements in the traps ranged from about 1.5 – 2.5 cm/year, while replicates in Southeast Loch ranged from 0.76 – 2.2 cm/year. Thus variation among station replicates was generally with a factor of 2-3.

Variations in sedimentation fluxes across sites are associated with differences in deposition rates, regional contaminant loading, and existing site conditions for bed concentrations. In general, it appears that for most metals, sedimentation at Bishop Point has the potential to reduce contaminant concentrations in the bed, while sedimentation at Southeast Loch may be acting as a source for copper and zinc (Figure 7-7). For PAHs, sedimentation tended to act as a source to the sediments of both sites for low molecular weight compounds, but generally acted as a recovery mechanism for higher molecular weight PAHs (> Chrysene; Figure 7-8). The magnitude of the PAH sedimentation pathway was much stronger at Southeast Loch compared to Bishop Point, both for source and recovery processes. The variation with molecular weight suggests that the particles that are depositing to the bed contain a fresher, less weathered mixture of PAHs, that is comparatively enriched in low molecular weight compounds, while the PAH mixture in the bed has been modified through preferential weathering and degradation of the low molecular weight fraction. This hypothesis is supported by the observation of high instantaneous biodegradation rates for naphthalene, phenanthrene and fluoranthene in surface sediments.

		Settling Flux				
		Rep 1	Rep 2	Rep 3	Average	Stdev.
Bishop Point	Arsenic	521	664	407	531	129
	Copper	3759	4794	2936	3830	931
	Cadmium	35	45	27	36	9
	Lead	4237	5404	3309	4317	1050
	Nickel	822	1048	642	837	204
	Manganese	-3813	-4863	-2978	-3884	945
	Silver	17	22	13	17	4
	Zinc	15572	19862	12163	15866	3858
Southeast Loch	Arsenic	238	112	81	144	83
	Copper	-5242	-2479	-1796	-3172	1825
	Cadmium	21	10	7	13	7
	Lead	2195	1038	752	1328	764
	Nickel	244	115	84	148	85
	Manganese	-23469	-11098	-8040	-14202	8170
	Silver	18	8	6	11	6
	Zinc	-4511	-2133	-1545	-2730	1570

Table 7-5. Settling flux rates for metals at Bishop Point and Southeast Loch including individual replicate fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .

		Settling Flux				
		Rep 1	Rep 2	Rep 3	Average	Stdev.
Bishop Point	Naphthalene	-0.8	-1.0	-0.6	-0.8	0.2
	Acenaphthylene	1.5	1.9	1.2	1.5	0.4
	Acenaphthene	-39	-50	-31	-40	10
	Fluorene	-87	-111	-68	-88	21
	Phenanthrene	-638	-813	-498	-650	158
	Anthracene	-149	-190	-117	-152	37
	Fluoranthene	-686	-874	-535	-698	170
	Pyrene	-169	-216	-132	-173	42
	Benzo(a)anthracene	-145	-185	-114	-148	36
	Chrysene	-112	-143	-88	-115	28
	Benzo(b)fluoranthene	390	498	305	398	97
	Benzo(k)fluoranthene	321	410	251	327	80
	Benzo(e)pyrene	256	326	200	261	63
	Benzo(a)pyrene	360	459	281	367	89
	Perylene	73	93	57	74	18
	Indeno(1,2,3-c,d)pyrene	151	192	118	154	37
	Dibenz(a,h)anthracene	1.3	1.6	1.0	1.3	0.3
	Benzo(g,h,i)perylene	90	115	70	92	22
Southeast Loch	Naphthalene	-1.0	-0.5	-0.3	-0.6	0.3
	Acenaphthylene	1.4	0.7	0.5	0.8	0.5
	Acenaphthene	-5.0	-2.4	-1.7	-3.0	1.8
	Fluorene	-27	-13	-9	-16	9.3
	Phenanthrene	-153	-72	-52	-92	53
	Anthracene	-60	-29	-21	-36	21
	Fluoranthene	-193	-91	-66	-117	67
	Pyrene	77	36	26	46	27
	Benzo(a)anthracene	-46	-22	-16	-28	16
	Chrysene	-57	-27	-19	-34	20
	Benzo(b)fluoranthene	105	50	36	64	37
	Benzo(k)fluoranthene	86	41	30	52	30
	Benzo(e)pyrene	46	22	16	28	16
	Benzo(a)pyrene	86	41	29	52	30
	Perylene	18	8.7	6.3	11	6.4
	Indeno(1,2,3-c,d)pyrene	12	5.6	4.1	7.2	4.1
	Dibenz(a,h)anthracene	3.8	1.8	1.3	2.3	1.3
	Benzo(g,h,i)perylene	10	4.8	3.5	6.1	3.5

Table 7-6. Settling flux rates for PAHs at Bishop Point and Southeast Loch including individual replicate fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .



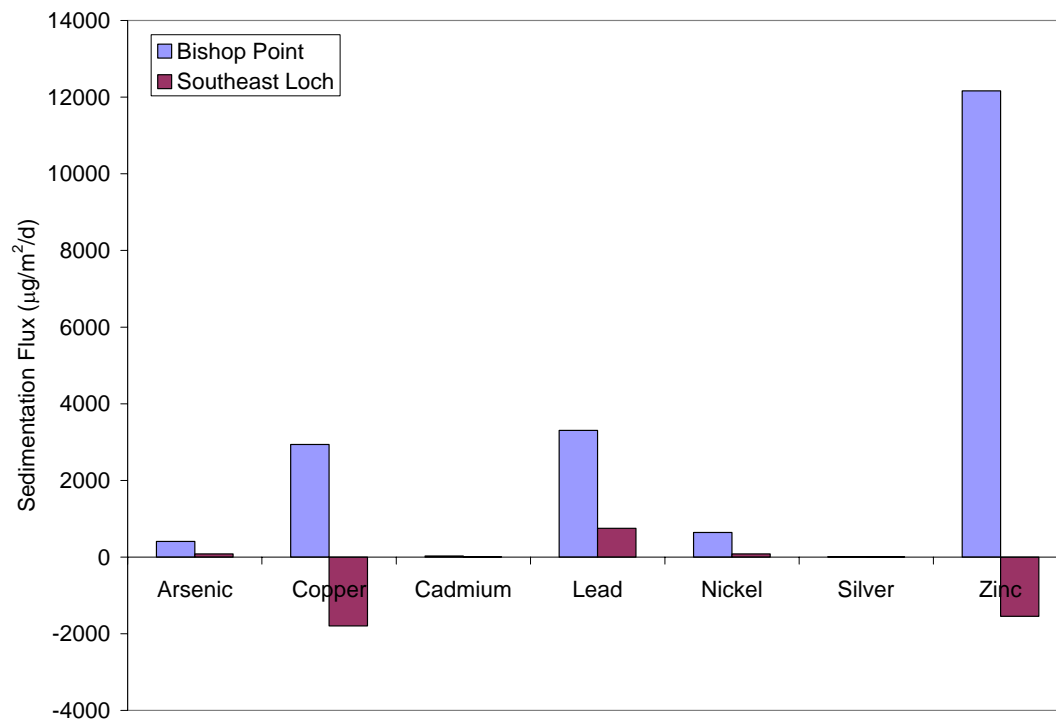


Figure 7-7. Comparison of site-average settling metal fluxes for the Bishop Point and Southeast Loch sites.

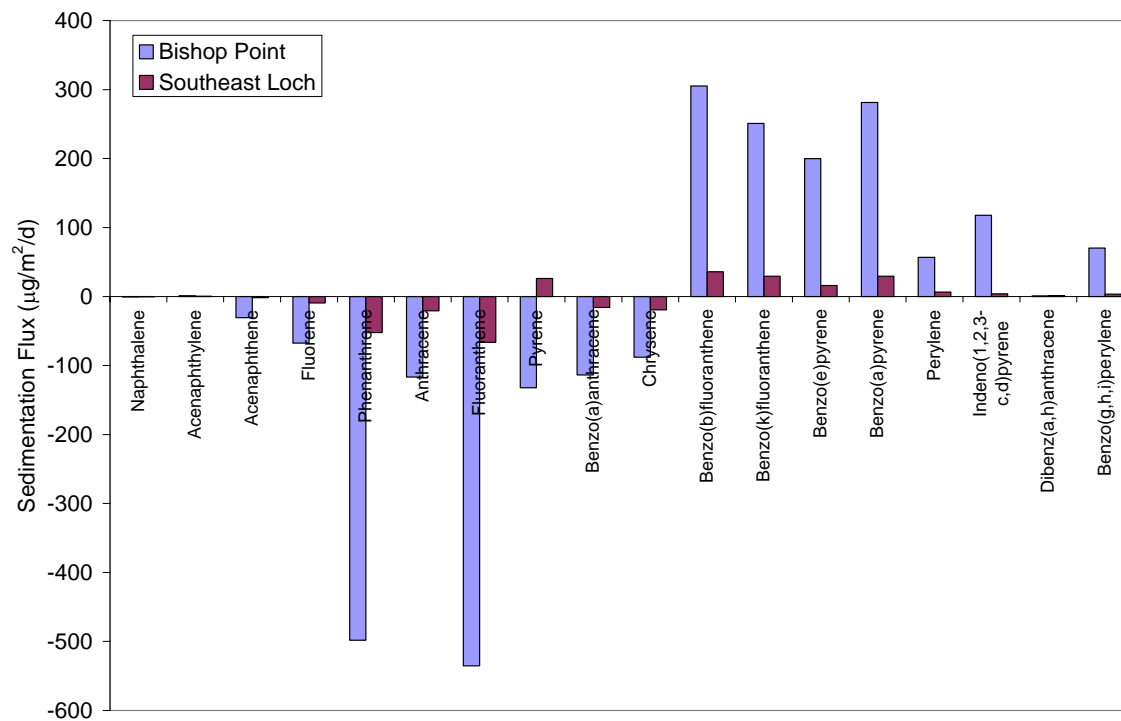


Figure 7-8. Comparison of site-average settling PAH fluxes for the Bishop Point and Southeast Loch sites.

#### 7.4 FLUX BY EROSION/RESUSPENSION

Fluxes associated with erosion were evaluated from critical shear stress ( $\tau_c$ ) and erosion rate ( $K_E$ ) characteristics measured by the flumes, bed shear stresses ( $\tau$ ) estimated from the current meters, and the contaminant concentrations measured within and below the mixed layer ( $c_H$ ,  $c_{H-}$ ). If the bed shear stress at the site exceeds the critical shear stress, then the potential exists for sediments to be eroded from the bed and transported by the harbor currents. In this case, the amount of erosion depends on the erosion rate characteristics of the bed as a function of depth, and the strength, variability, and duration ( $T$ ) of the applied shear stress. The erosion flux was calculated from the sediment flume and current meter data as

$$F_E = \frac{c_H - c_{H-}}{T} \int_0^T K_E(z)(\tau(t) - \tau_c) dt$$

For both Bishop Point and Southeast Loch, the bottom shear stress estimated from the current meters was always less than the critical shear stress. This implies that the flux associated with erosion is negligible, at least under the conditions represented by the current meter deployments. Because of the relatively deep water at the sites, shear stress related to storm events is also expected to be below critical shear stress. It is likely, although it was not observed, that propeller generated shear stresses would exceed the critical shear stress at both sites during ship and tug movements. This is particularly true for the unconsolidated sediments found in Southeast Loch. However, for purposes of this analysis, the bed is assumed to be stable, and the erosion flux to be negligible.

##### Variability of the measurement

Variability for the erosion flux was quantified based on (1) variations in the current meter time-series record at each station, (2) variation in critical shear stress and erosion rate determined by two different flume systems, the in-situ annular Sea Carousel, and the axial laboratory SedFlume, (3) variation in contaminant concentrations below and within the mixed layer between stations within the same site, and (4) variation in bed stress, critical shear stress, erosion rate, and chemical concentrations across the two sites. Variability of the erosion flux itself was not assessed because the erosion flux was estimated to be negligible based on the observed bed stress.

Variability in the bed stress as estimated by near-bottom current meters was influenced primarily by tidal and wind driven forcing of water currents. Tidal variations in Pearl Harbor are smaller than many coastal sites, and this was particularly true for the Southeast Loch site which is located at the head of the Loch and is thus subjected to a minimum of tidal through flow. Because of its location near the entrance channel to Pearl Harbor, the Bishop Point site is subject to higher tidal fluctuation in currents. Tidal fluctuations of near-bottom currents at the Southeast Loch site were generally <1 cm/s, while for Bishop Point, tidal fluctuations were generally <5 cm/s. These components appeared to be relatively consistent during the measurement period, but may fluctuate seasonally depending on wind patterns and river flow.

Variability between the bed properties measured by the two flume types reflect small-scale differences in the exact point of measurement, and methodological differences associated with the collection and/or analysis of the samples. Sea Carousel measurements were made in situ,

while SedFlume measurements were made on cores that were transported to the flume facility in San Diego. Holding times and disturbance or consolidation of the cores during transport may alter the measured bed properties. Different data analysis methods may also lead to variation in results, even for identical samples. In general, we found that critical shear stress values measured by the two methods agreed within a factor of about 2-3, with the SedFlume results being higher than those measured with the Sea Carousel.

Within site variability of measured contaminant concentrations below and within the sediment mixed layer is important in assessing the potential for erosive flux. If the concentration in the mixed layer is lower than the concentration in the deep layer, then as the surface layer erodes the concentration in the mixed layer will increase. In general, we found that concentrations in the mixed layer at the three stations within Bishop Point varied from about 7-75% (RSD) for metals, and 21-61% for PAHs. For Southeast Loch the variability for metals was somewhat lower (1-24%), but somewhat higher for PAHs (30-149%).

Variation in erosion flux between the two sites was not observed because results indicated that the erosion flux was negligible at both sites. There were observed variations between the sites in bed stress, critical shear stress, erosion rate, and chemical concentrations. In general, we found that both the bed stress and the critical shear stress were lower at Southeast Loch compared to Bishop Point. Chemical concentrations also showed variation between the sites. Variations in the vertical contaminant gradients reveal differences in the potential for erosion to drive a chemical flux. For example, the vertical gradient observed in the shallow cores ( $C_H - C_D$ ) suggests that for most metals at both sites erosion of the bed would decrease the concentration in the surface layer (Figure 7-9). Results for PAHs were not as consistent, with the Bishop Point data indicating a potential increase in concentration for some PAHs and Southeast Loch having a potential decrease for most PAHs. These results are inconsistent with the results from the deeper cores at BPC and SLC which would indicate that if erosion extended to depths greater than the mixed layer, the concentrations of PAHs would increase at Southeast Loch and decrease at Bishop Point. However, based on the lack of observed or predicted erosion at these sites, it seems unlikely that an event of this magnitude would occur.

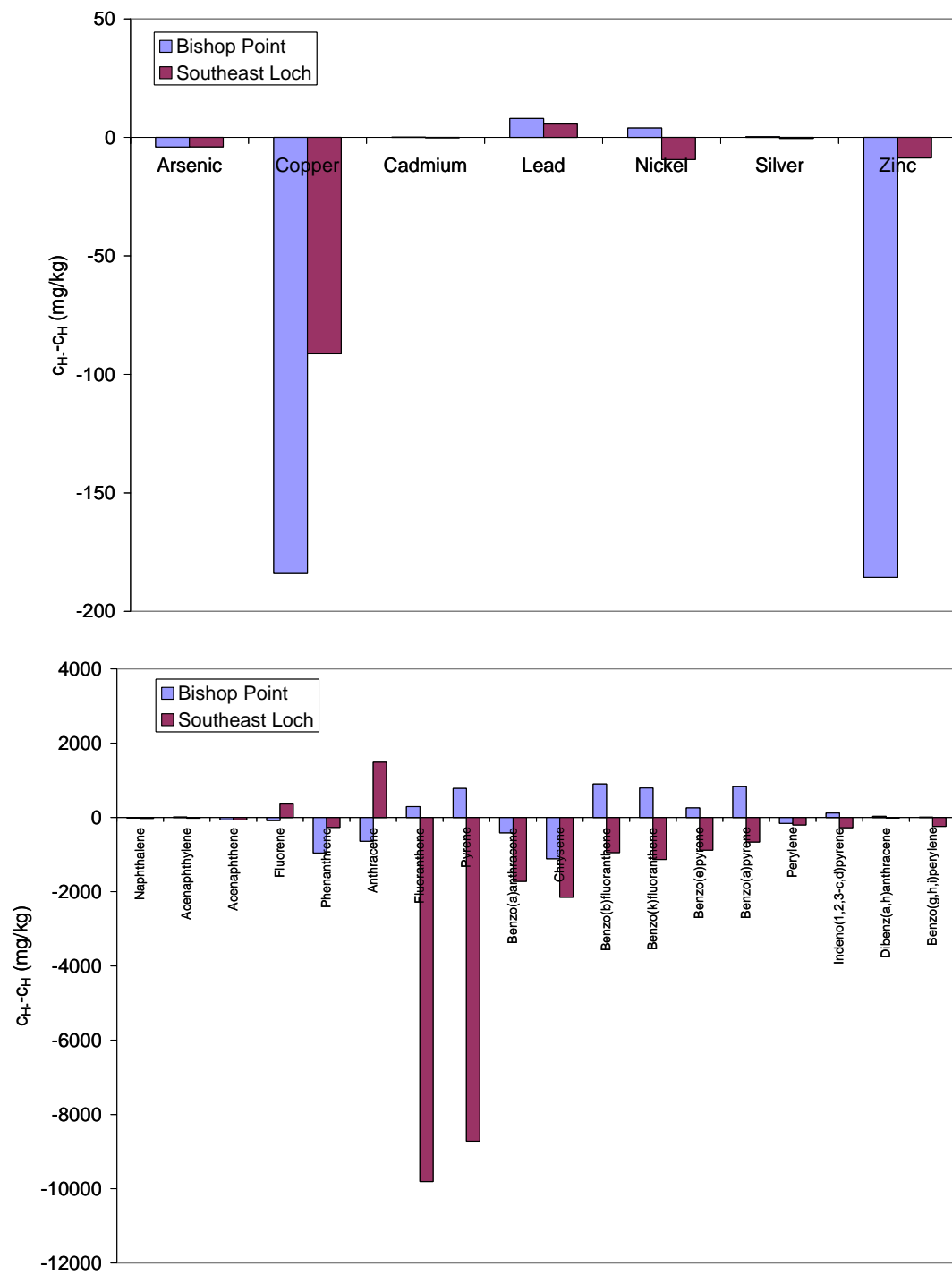


Figure 7-9. Site-average vertical gradients in metals and PAHs from the shallow cores at Southeast Loch and Bishop Point.

## 7.5 FLUX BY BIODEGRADATION

Fluxes associated with biodegradation were evaluated from core profiles of measured short-term mineralization rates ( $R_D$ ) of radio labeled additions to site sediments. Measurements were limited to three PAHs including naphthalene, phenanthrene and fluoranthene. The biodegradation flux for these three compounds was estimated in two ways. The first estimate was made from the core profiles and mixing depth by calculating the integral-average mineralization rate over the mixed layer depth ( $H$ ) as

$$F_B = \int_0^H R_D(z) dz$$

This estimate is based on the assumption that aerobic biodegradation of PAHs occurs within the mixed layer at the measured rates as a function of depth. The second estimate was made from only the measured surface mineralization rate ( $R_{DSURF}$ ) and applied to the measured oxygen penetration depth ( $H_{O_2}$ ) as

$$F_B = H_{O_2} R_{DSURF}$$

The second estimate is based on the assumption that aerobic biodegradation at the rates measured will only occur in the presence of oxygen within the sediment column. Alternatively, this estimate could be viewed to be based on the assumption that the time that a mixed layer particle spends in the aerobic zone is proportional to the ratio of the aerobic layer depth to the mixed layer depth. Biodegradation fluxes were calculated for each station at each site based on the equations above. The site-mean flux was then calculated as the average of the stations fluxes within the site. Results for the measured PAHs are shown in Table 7-7.

### Variability of the measurement

Variability for biodegradation fluxes was quantified based on (1) variation in mineralization rates within the core profiles at individual stations, (2) variations in rates at different stations within the same site, and (3) variation in rates across the two sites. As described above, variations associated with different assumptions about the active depth of biodegradation were also examined.

Variability within cores was examined based on triplicate measurements at each core depth interval. For the Bishop Point cores, RSDs for mineralization rates within the depth intervals were found to range from about 12-173% for naphthalene, 68-128% for phenanthrene, and 87-173% for fluoranthene. Similar ranges were found for Southeast Loch cores.

Variability at different stations within the same site was examined based on the comparison of depth-integrated and surface layer average mineralization rates between the two stations at each site. For Bishop Point, RPDs for the depth-integrated rates ranged from a low of 46% for naphthalene to a high of 80% for fluoranthene (Table 7-7). Variability based on the surface layer rates was higher, ranging from 100% for naphthalene to 200% for phenanthrene. Similar ranges were observed in Southeast Loch.

Variability across the two sites was evaluated based on comparison of the site-average degradation flux rates for both the depth-integrated assumption and the surface layer assumption. In general, both sites showed a similar pattern in terms of the magnitude of the flux with P>F>N (Figure 7-10 and Figure 7-11). Degradation fluxes were higher for naphthalene and phenanthrene at the Southeast Loch site, and higher for fluoranthene at the Bishop Point site. This pattern appears to be consistent with the predominance of lower molecular weight PAHs at Southeast Loch.

Site	Station	Depth Integrated Core			Surface Layer		
		N	P	F	N	P	F
Bishop Point	BPB	63	1134	304	5	69	29
	BPC	100	691	131	2	0	1
	Average	81	913	218	3	34	15
	RPD	46%	49%	80%	100%	200%	190%
Southeast Loch	SLA	175	1988	123	9	39	2
	SLC	47	2267	219	1	52	7
	Average	111	2127	171	5	45	4
	RPD	116%	13%	56%	151%	28%	115%

Table 7-7. Depth-integrated and surface layer biodegradation flux rates for PAHs at Bishop Point and Southeast Loch including individual station fluxes, and site-average fluxes. All values are  $\mu\text{g}/\text{m}^2/\text{d}$ .

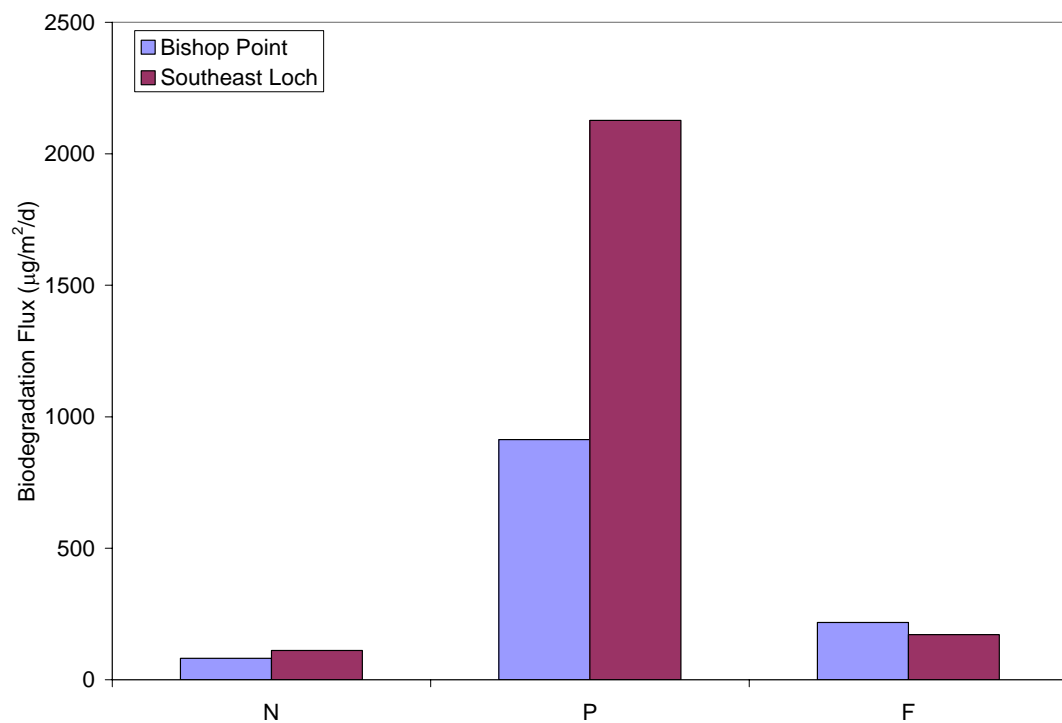


Figure 7-10. Comparison of site-average biodegradation fluxes for depth-integrated cores at the Bishop Point and Southeast Loch sites.

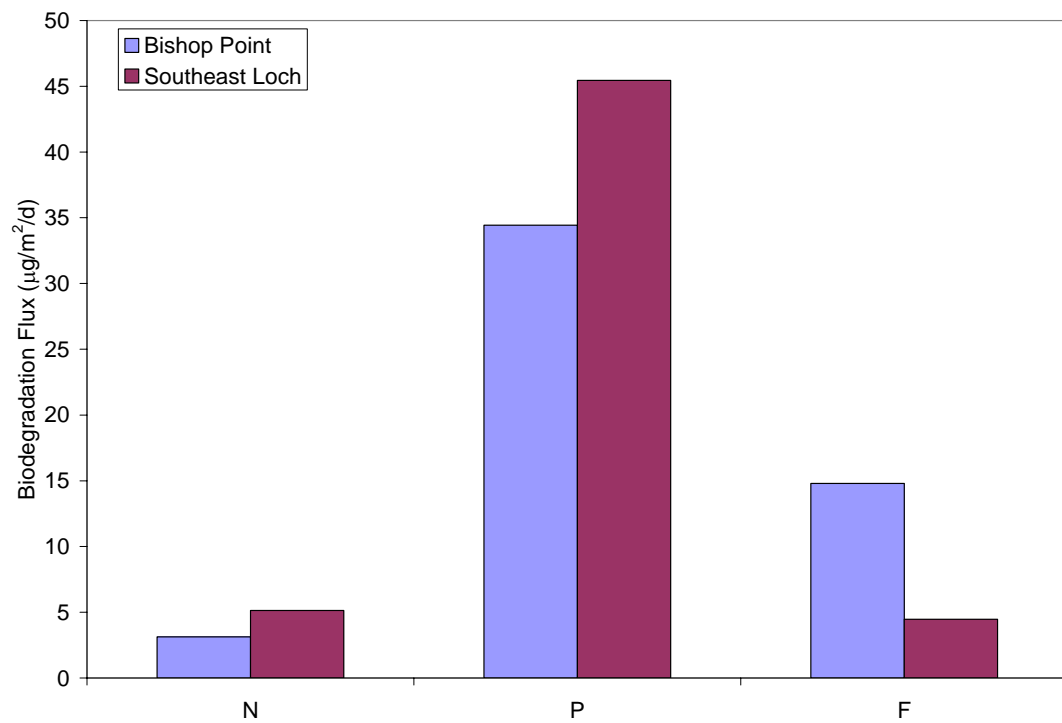


Figure 7-11. Comparison of site-average biodegradation fluxes for surface layer sediments at the Bishop Point and Southeast Loch sites.

## 7.6 PATHWAY ANALYSIS FOR METALS

The PRISM pathway analysis for metals in Pearl Harbor was carried out by comparing the raw flux rates associated with each pathway. The analysis provides a means of evaluating which pathways may be dominant for the given site where the measurements were conducted. The primary pathways that were evaluated for metals at each site included

- Diffusive Flux (combined molecular and bio)
- Advective Flux
- Sedimentation Flux
- Erosion Flux

Comparative fluxes for all metals are summarized in Table 7-8. Convention for the fluxes in the pathway analysis is that a positive flux indicates a loss of contaminant from the surface layer, and a negative flux indicates a source of contaminant to the surface layer. Estimates of the variability for each metal at each site are included. In general, the variability estimates were compiled from propagation formulas that account for variability in the individual parameters within each pathway flux equation. Results are presented below for individual metals that were identified as CPoCs at the initiation of the study.

### Arsenic

Pathway analysis for arsenic indicates that most processes are leading to a loss of arsenic in the surface layer at both sites (Figure 7-12). Advection, diffusion and predominantly settling fluxes all indicate that Southeast Loch sediments are losing arsenic either by migration to the water column, or by burial from cleaner incoming material. Similarly, diffusion and predominantly settling fluxes indicate that Bishop Point sediments are losing arsenic either by migration to the water column, or by burial from cleaner incoming material. The negative advection flux at Southeast Loch suggests that deep porewater may be acting as a weak source to the surface layer sediments. Erosion is negligible. The magnitude of the settling and diffusion fluxes at the two sites were comparable, while the magnitude of the advective fluxes were also similar but of opposite sign. Within-site variability in the two areas indicates that settling fluxes are positive throughout both sites, while advective and diffusive fluxes may vary from positive to negative based on within-site conditions.

### Copper

Pathway analysis for copper indicates that variations in surface layer concentrations at both sites are dominated by settling fluxes (Figure 7-13). The settling flux at Southeast Loch is acting as a source of copper to the sediment surface layer, while the settling flux at Bishop Point is acting as a loss of copper to the sediment surface layer. Advection, diffusion and erosion are all negligible relative to settling. The magnitude of the settling fluxes at the two sites were comparable, but of opposite sign. Within-site variability in the two areas indicates that settling fluxes are variable throughout both sites and may vary from positive to negative based on within-site conditions.

### Cadmium

Pathway analysis for cadmium indicates that variations in surface layer concentrations at both sites are dominated by settling fluxes (Figure 7-14). The settling flux at both sites is acting as a loss of cadmium from the sediment surface layer. Diffusion is also acting as a secondary loss



process at Southeast Loch, while advection represents a weak source process at Bishop Point. Otherwise, advective, diffusion and erosion are all negligible relative to settling. The settling flux at Bishop Point was approximately twice the magnitude of the flux at Southeast Loch. Within-site variability in the two areas indicates that settling fluxes are positive throughout both sites, diffusion is positive throughout Southeast Loch, and advection and diffusion otherwise may vary from positive to negative based on within-site conditions.

### **Lead**

Pathway analysis for lead indicates that variations in surface layer concentrations at both sites are dominated by settling fluxes (Figure 7-15). The settling flux at both sites is acting as a loss of lead from the sediment surface layer. Advection, diffusion and erosion are all negligible relative to settling. The magnitude of the settling flux at Bishop Point was approximately twice the flux at Southeast Loch. Within-site variability in the two areas indicates that settling fluxes are variable throughout both sites and may vary from positive to negative based on within-site conditions.

### **Nickel**

Pathway analysis for nickel indicates that advection, diffusion and settling may all be acting to balance the concentration of nickel in the surface layer at both sites (Figure 7-16). Both sites show the same pattern of processes with advection acting as a source, and diffusion and settling acting as a loss to the surface layer. The magnitude of the loss terms tends to balance the source terms at Southeast Loch, while the advective source term tends to dominate at Bishop Point. Erosion is negligible. Within-site variability in Southeast Loch indicates that settling and diffusive fluxes are positive throughout the site, while advective fluxes may vary from positive to negative based on within-site conditions. Within-site variability in Bishop Point indicates that settling, diffusive, and advective fluxes may vary from positive to negative based on within-site conditions.

### **Silver**

Pathway analysis for silver indicates that variations in surface layer concentrations at both sites are dominated by settling fluxes (Figure 7-17). The settling flux at Bishop Point is acting as a source of silver to the sediment surface layer, while the settling flux at Southeast Loch is acting as a loss of copper to the sediment surface layer. Diffusive fluxes act to balance the settling process at both sites, but the magnitude of the diffusive flux is approximately an order of magnitude lower than settling. Advective and erosion are negligible relative to settling. The magnitude of the settling fluxes at Bishop Point is about twice the flux at Southeast Loch, and of opposite sign. Within-site variability in the two areas indicates that settling fluxes are consistently positive throughout Southeast Loch, but may vary from positive to negative based on within-site conditions within Bishop Point.

### **Zinc**

Pathway analysis for zinc indicates that variations in surface layer concentrations at both sites are dominated by settling fluxes (Figure 7-18). The settling flux at Southeast Loch is acting as a source of zinc to the sediment surface layer, while the settling flux at Bishop Point is acting as a loss of zinc to the sediment surface layer. Relative to settling, advection and diffusion are acting as a secondary pathway of loss for zinc from the surface layer at Southeast Loch. Relative to settling, advection, diffusion and erosion are all negligible at Bishop Point. The magnitude of the

settling flux at Bishop Point was about one order of magnitude greater than at Southeast Loch, and of opposite sign. Within-site variability in the two areas indicates that settling fluxes are variable throughout both sites and may vary from positive to negative based on within-site conditions.

		PRISM Pathway Flux							
		Advection		Diffusion		Settling		Erosion	
		Site Mean	Estimated Var.	Site Mean	Estimated Var.	Site Mean	Estimated Var.	Site Mean	Estimated Var.
Bishop Point	Arsenic	-0.03	0.05	0.03	0.01	0.27	0.26	0	na
	Copper	0.01	0.02	0.03	0.11	9.8	16.4	0	na
	Cadmium	-0.0006	0.0012	0.0000	0.0015	0.0359	0.0223	0	na
	Lead	0.00	0.01	0.03	0.01	3.9	2.9	0	na
	Nickel	-0.63	1.04	0.02	0.03	0.07	0.66	0	na
	Manganese	3.0	4.5	2.1	3.1	-5.3	2.1	0	na
	Silver	0.0000	0.0000	0.0024	0.0006	-0.034	0.071	0	na
	Zinc	-0.31	0.63	0.30	0.10	26.1	29.5	0	na
Southeast Loch	Arsenic	0.03	0.05	0.02	0.06	0.16	0.13	0	na
	Copper	0.01	0.01	0.02	0.02	-6.6	7.9	0	na
	Cadmium	0.0001	0.0010	0.0035	0.0019	0.0212	0.0143	0	na
	Lead	0.00	0.00	0.00	0.01	1.9	2.0	0	na
	Nickel	-0.46	0.88	0.10	0.04	0.52	0.40	0	na
	Manganese	15.4	11.7	1.2	0.80	-5.7	7.3	0	na
	Silver	0.00005	0.00008	-0.0013	0.0000	0.014	0.011	0	na
	Zinc	0.13	0.11	0.36	0.16	-2.6	7.9	0	na

Table 7-8. Summary of PRISM pathway fluxes for metals at the Bishop Point and Southeast Loch sites. All fluxes are in mg/m<sup>2</sup>/d.

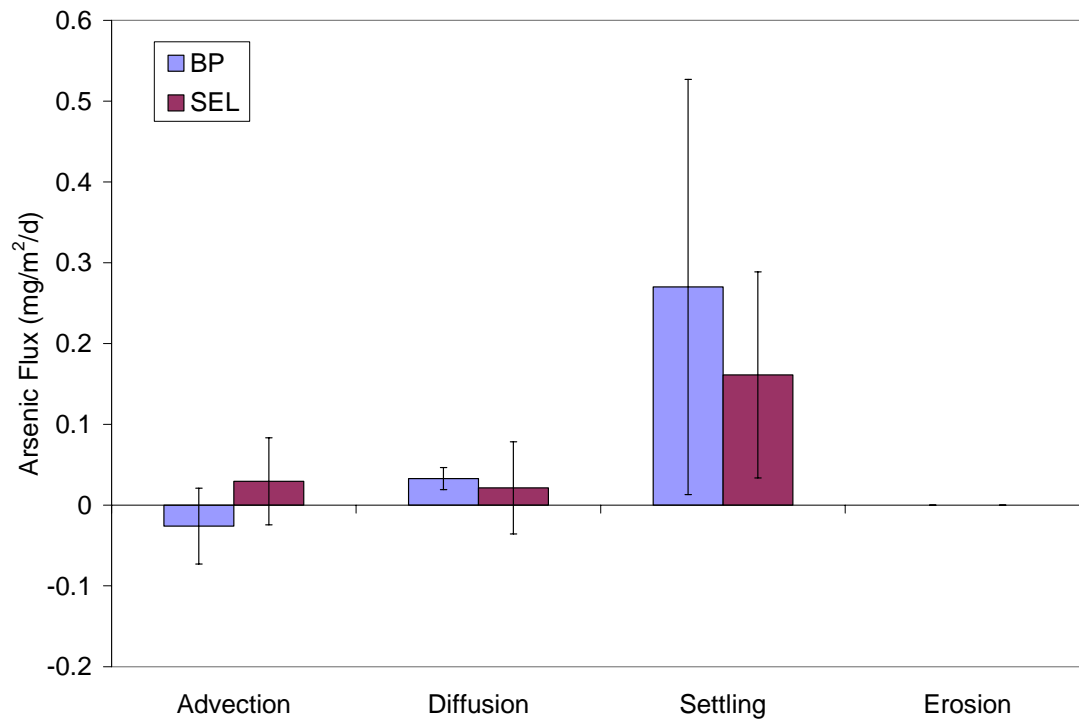


Figure 7-12. PRISM pathway fluxes for arsenic.

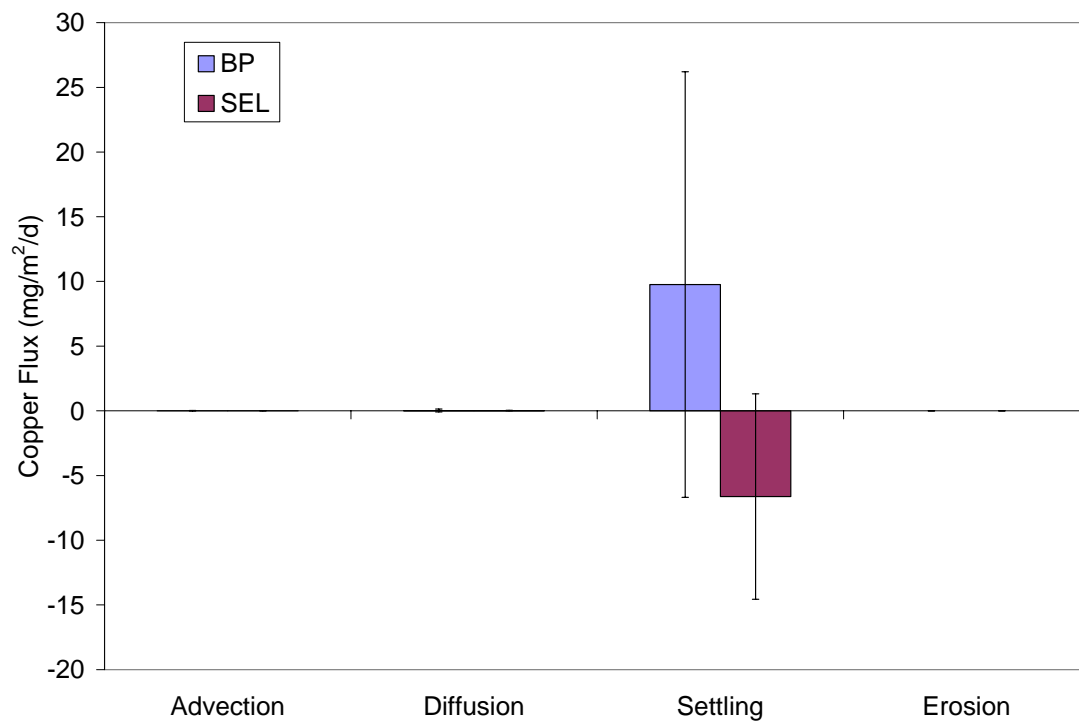


Figure 7-13. PRISM pathway fluxes for copper.

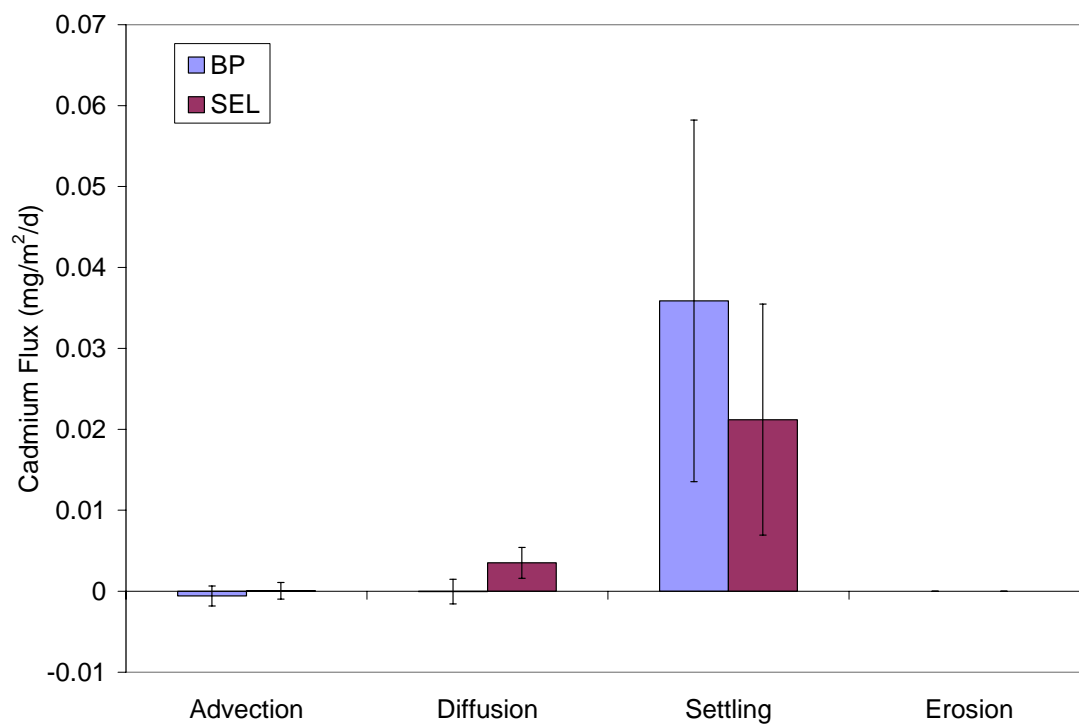


Figure 7-14. PRISM pathway fluxes for cadmium.

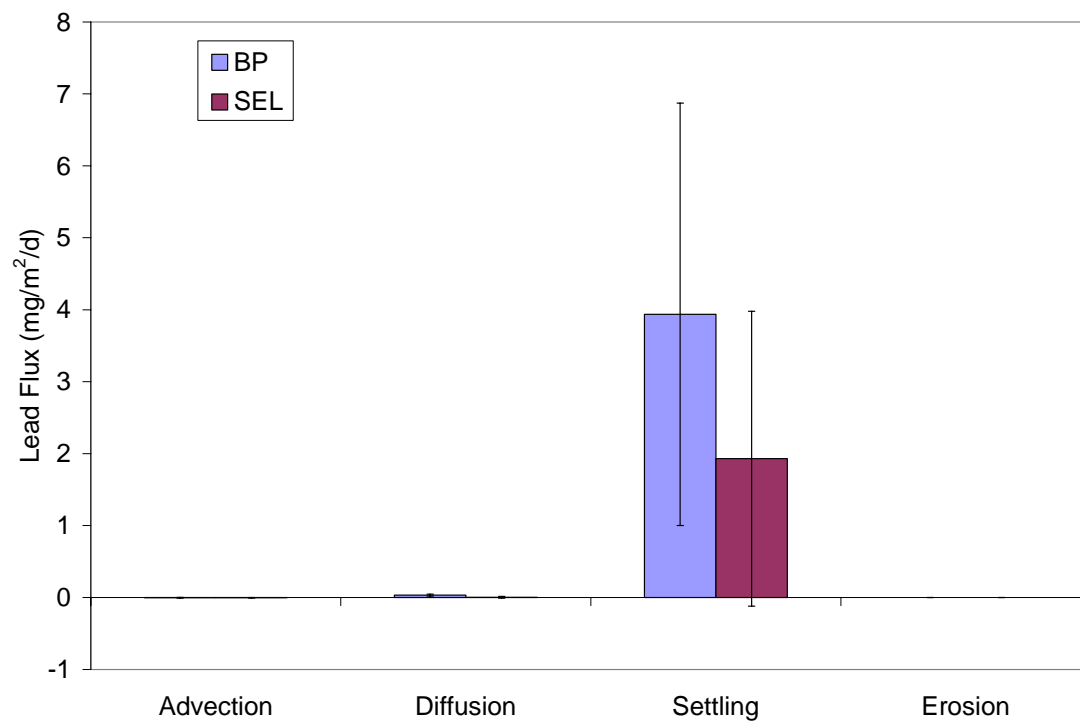


Figure 7-15. PRISM pathway fluxes for lead.

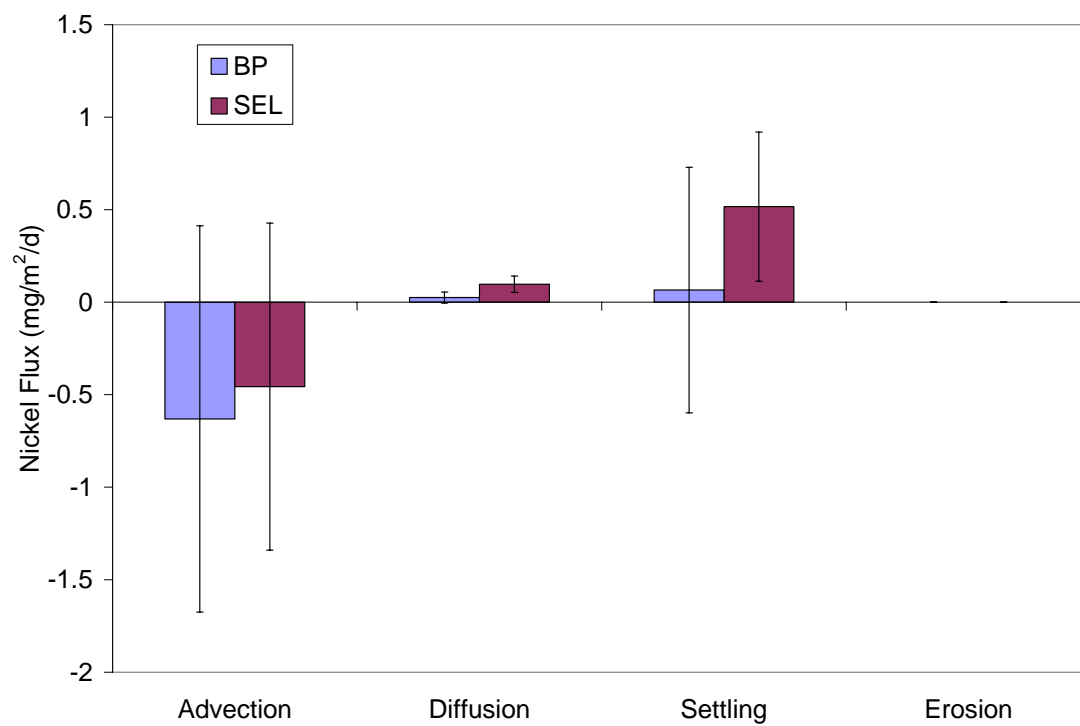


Figure 7-16. PRISM pathway fluxes for nickel.

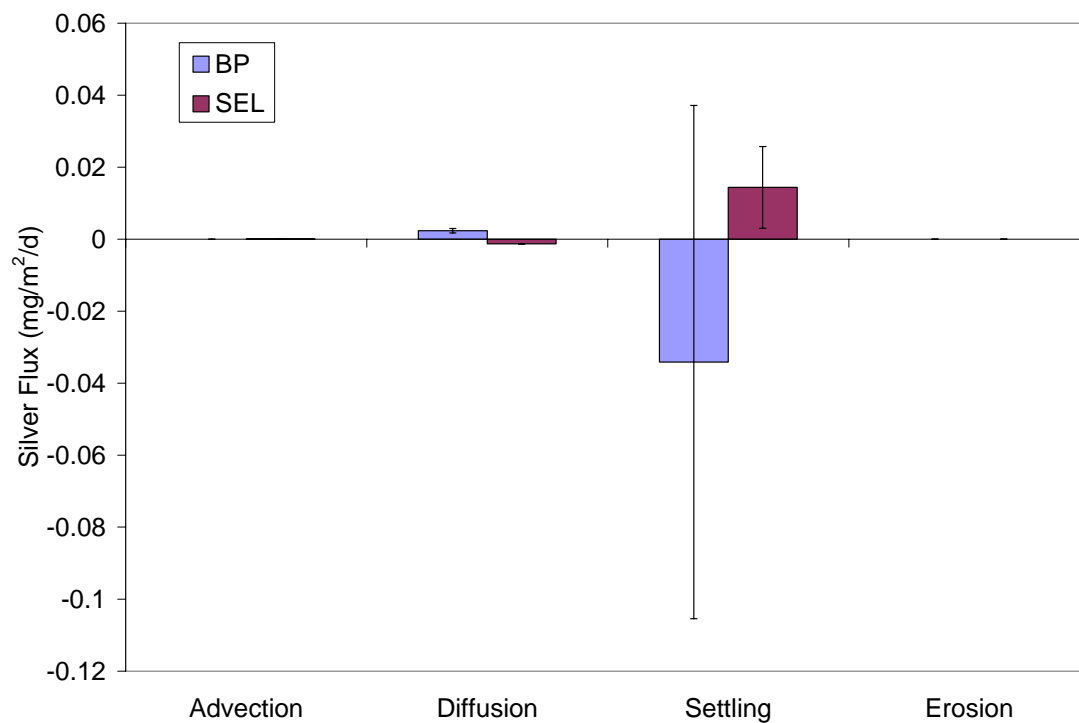


Figure 7-17. PRISM pathway fluxes for silver.

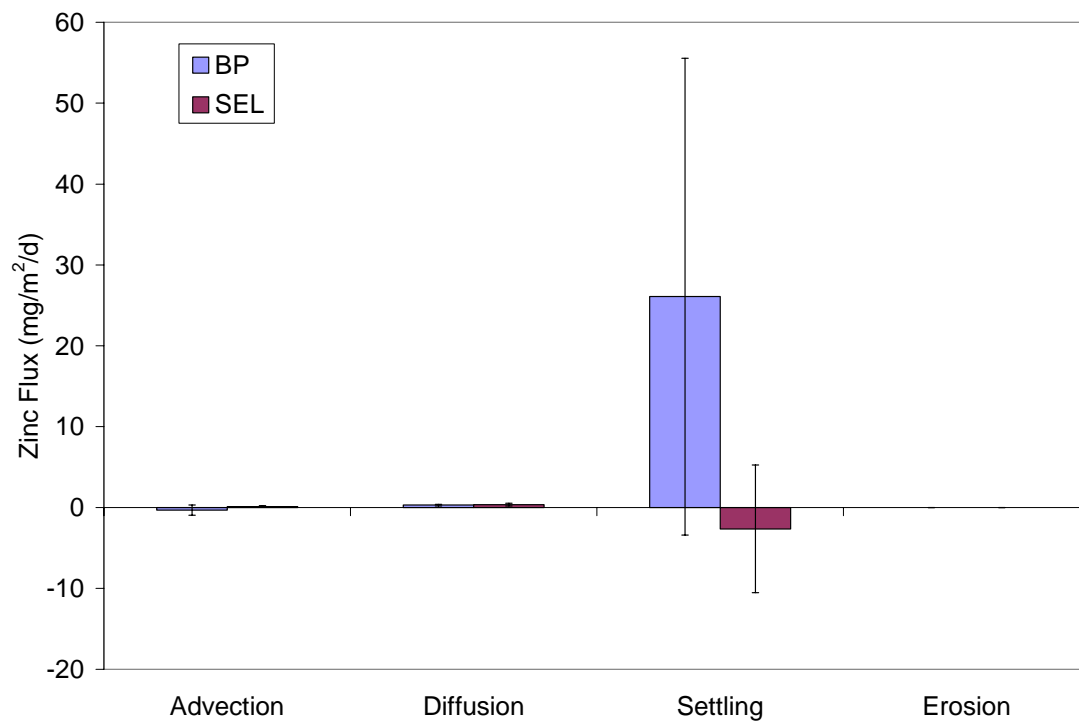


Figure 7-18. PRISM pathway fluxes for zinc.

## 7.7 PATHWAY ANALYSIS FOR PAHS

The PRISM pathway analysis for PAHs in Pearl Harbor was carried out by comparing the raw flux rates associated with each pathway. The analysis provides a means of evaluating which pathways may be dominant for the given site where the measurements were conducted. The primary pathways that were evaluated for metals at each site included

- Diffusive Flux (combined molecular and bio)
- Advective Flux
- Sedimentation Flux
- Erosion Flux
- Biodegradation Flux

Comparative fluxes for all PAHs are summarized in Table 7-9. Convention for the fluxes in the pathway analysis is that a positive flux indicates a loss of contaminant from the surface layer, and a negative flux indicates a source of contaminant to the surface layer. Estimates of the variability for each PAH at each site are included. In general, the variability estimates were compiled from propagation formulas that account for variability in the individual parameters within each pathway flux equation. Results are presented below for individual PAHs including naphthalene, phenanthrene, and fluoranthene for which all pathways were quantified.

### Naphthalene

Pathway analysis for naphthalene was examined for the two biodegradation assumptions (depth-integrated and surface layer; Figure 7-19). Applying the depth-integrated degradation flux, the pathway analysis indicates that variations in surface layer concentrations at both sites are dominated by biodegradation fluxes. Relative to the depth-integrated biodegradation, settling, advection, diffusion and erosion are all negligible at Bishop Point, and only advection appears to be significant at Southeast Loch. Advection at Southeast Loch was about four times less than degradation, but also acts as a loss to the surface layer of the sediment. The magnitude of the degradation flux at the two sites was comparable. Within-site variability in the two areas indicates that depth-integrated degradation fluxes are fairly consistent within the two sites.

Applying the surface layer degradation flux, the pathway analysis indicates that variations in surface layer concentrations at Bishop Point are influenced by advection, and degradation, and to a lesser extent by diffusion and settling (Figure 7-19). At Southeast Loch, variations in surface layer concentrations are dominated by degradation and advection. In all cases, the pathway analysis indicates significant unbalanced losses of naphthalene from the surface layer of the sediment, suggesting that this PAH is unlikely to persist at elevated concentrations under current conditions. The high degradation fluxes may be indicative of degradation “potential” rather than the actual rate, given that if this rate persisted in the absence of any significant source, the naphthalene would be completely depleted in a very short time. This is consistent with the low concentrations generally observed in the mixed layer sediments at both sites.

### Phenanthrene

Pathway analysis for phenanthrene was examined for the two biodegradation assumptions (depth-integrated and surface layer; Figure 7-20). Applying the depth-integrated degradation

flux, the pathway analysis indicates that variations in surface layer concentrations are balanced by settling and degradation at the Bishop Point site, and are dominated by biodegradation fluxes at the Southeast Loch site. Relative to the depth-integrated biodegradation and settling, advection, diffusion and erosion are all negligible at Bishop Point. At Southeast Loch, all other processes were negligible relative to depth-integrated degradation. The magnitude of the degradation flux at the Southeast Loch site was about twice that at Bishop Point. Within-site variability in the two areas indicates that depth-integrated degradation fluxes are fairly consistent within the two sites.

Applying the surface layer degradation flux, the pathway analysis indicates that variations in surface layer concentrations at Southeast Loch are balanced by sources from advection, diffusion and settling, and losses from degradation (Figure 7-20). At Bishop Point, variations in surface layer concentrations are dominated by input fluxes from settling. Fluxes for advection, diffusion erosion and surface layer degradation were all negligible relative to settling at Bishop Point.

### **Fluoranthene**

Pathway analysis for fluoranthene was examined for the two biodegradation assumptions (depth-integrated and surface layer; Figure 7-21). Applying the depth-integrated degradation flux, the pathway analysis indicates that variations in surface layer concentrations are balanced by settling and degradation at the Bishop Point site. At the Southeast Loch site, variations in surface layer concentrations are balanced by inputs from advection, and losses from settling and degradation. Relative to the settling flux, advection, diffusion and erosion are all negligible at Bishop Point. At Southeast Loch diffusion and erosion were negligible. The magnitude of the degradation flux at the Southeast Loch site was comparable to that at Bishop Point, while the magnitude of the settling flux at Bishop Point was about four times larger than that at Southeast Loch, and of opposite sign. Within-site variability in the two areas indicates that depth-integrated degradation fluxes are fairly consistent within the two sites.

Applying the surface layer degradation flux, the pathway analysis indicates that variations in surface layer concentrations at Southeast Loch are balanced between sources from advection, and losses from degradation (Figure 7-21). At Bishop Point, variations in surface layer concentrations are dominated by input fluxes from settling.



		Advection		Diffusion		Settling		Erosion		Depth-Integrated Degradation		Surface-Layer Degradation	
		Site Mean	Est. Var.	Site Mean	Est. Var.	Site Mean	Est. Var.	Site Mean	Est. Var.	Site Mean	Est. Var.	Site Mean	Est. Var.
Bishop Point	Naphthalene	0.9	1.5	0.2	0.7	-1.1	0.6	0.0	na	81	27	3.2	2.2
	Phenanthrene	18	30	0	1	-914	461	0.0	na	913	313	35	50
	Fluoranthene	19	31	2	2	-981	451	0.0	na	218	123	15	23
Southeast Loch	Naphthalene	22	40	-0.2	0.3	0.7	2.1	0.0	na	111	91	5.2	7.8
	Phenanthrene	-21	31	-0.3	0.6	-32	63	0.0	na	2127	197	46	51
	Fluoranthene	-130	208	-0.9	0.7	267	613	0.0	na	171	68	4.5	5.3

Table 7-9. Summary of PRISM pathway fluxes for PAHs at the Bishop Point and Southeast Loch sites. All fluxes are in  $\mu\text{g}/\text{m}^2/\text{d}$ .

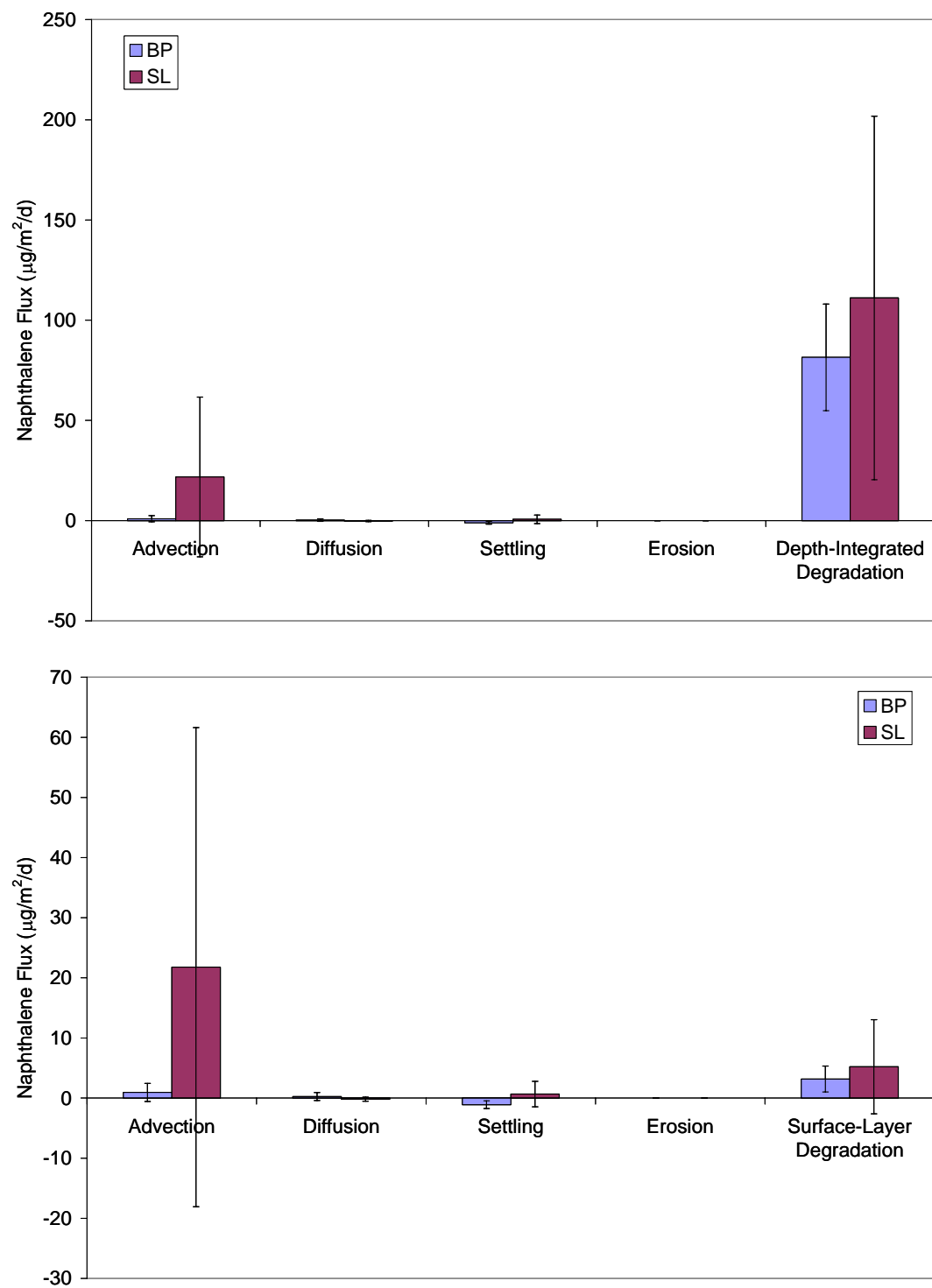


Figure 7-19. PRISM pathway fluxes for naphthalene including comparison for depth-integrated biodegradation (top) and surface-layer biodegradation (bottom).

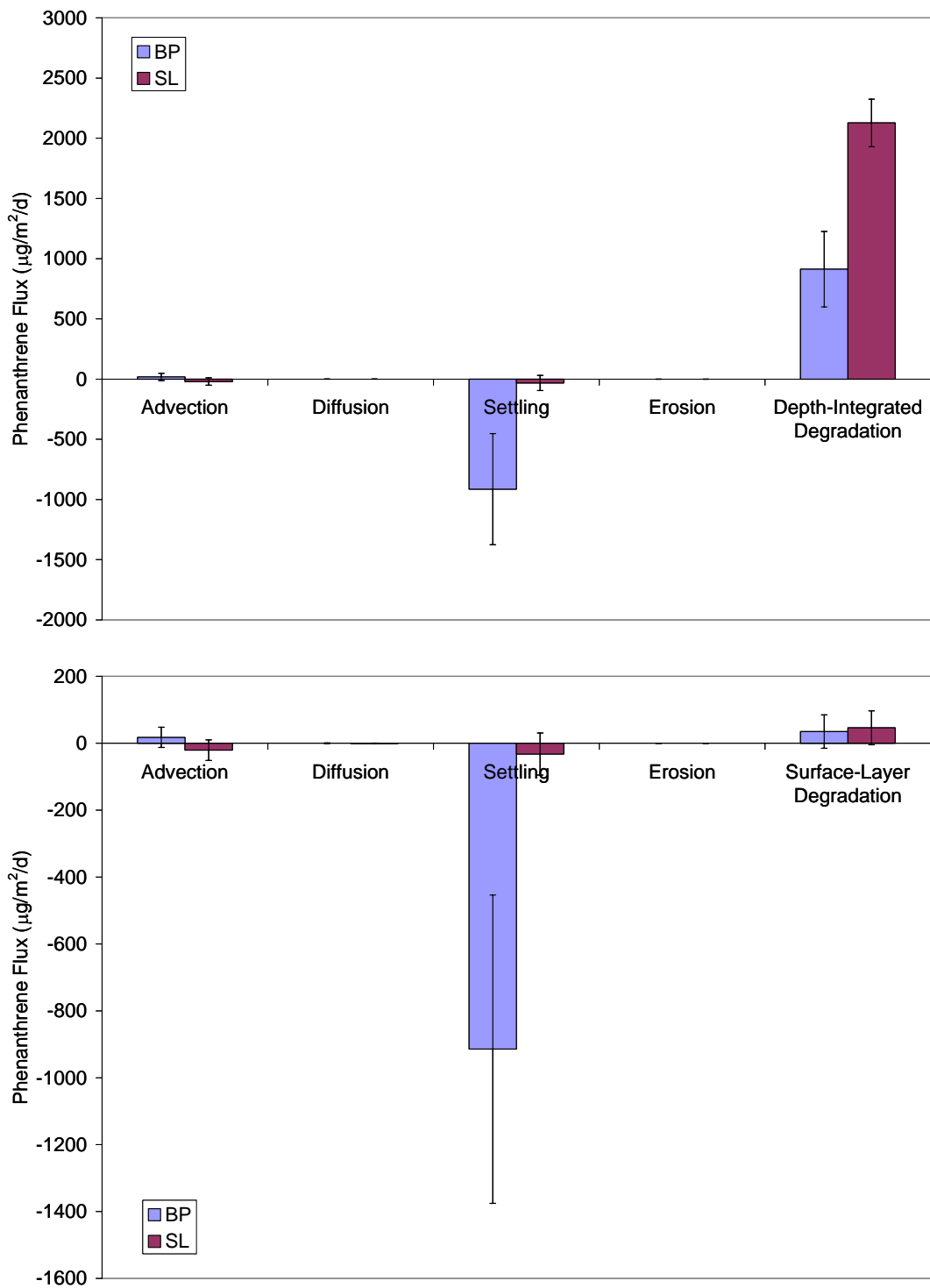


Figure 7-20. PRISM pathway fluxes for phenanthrene including comparison for depth-integrated biodegradation (top) and surface-layer biodegradation (bottom).

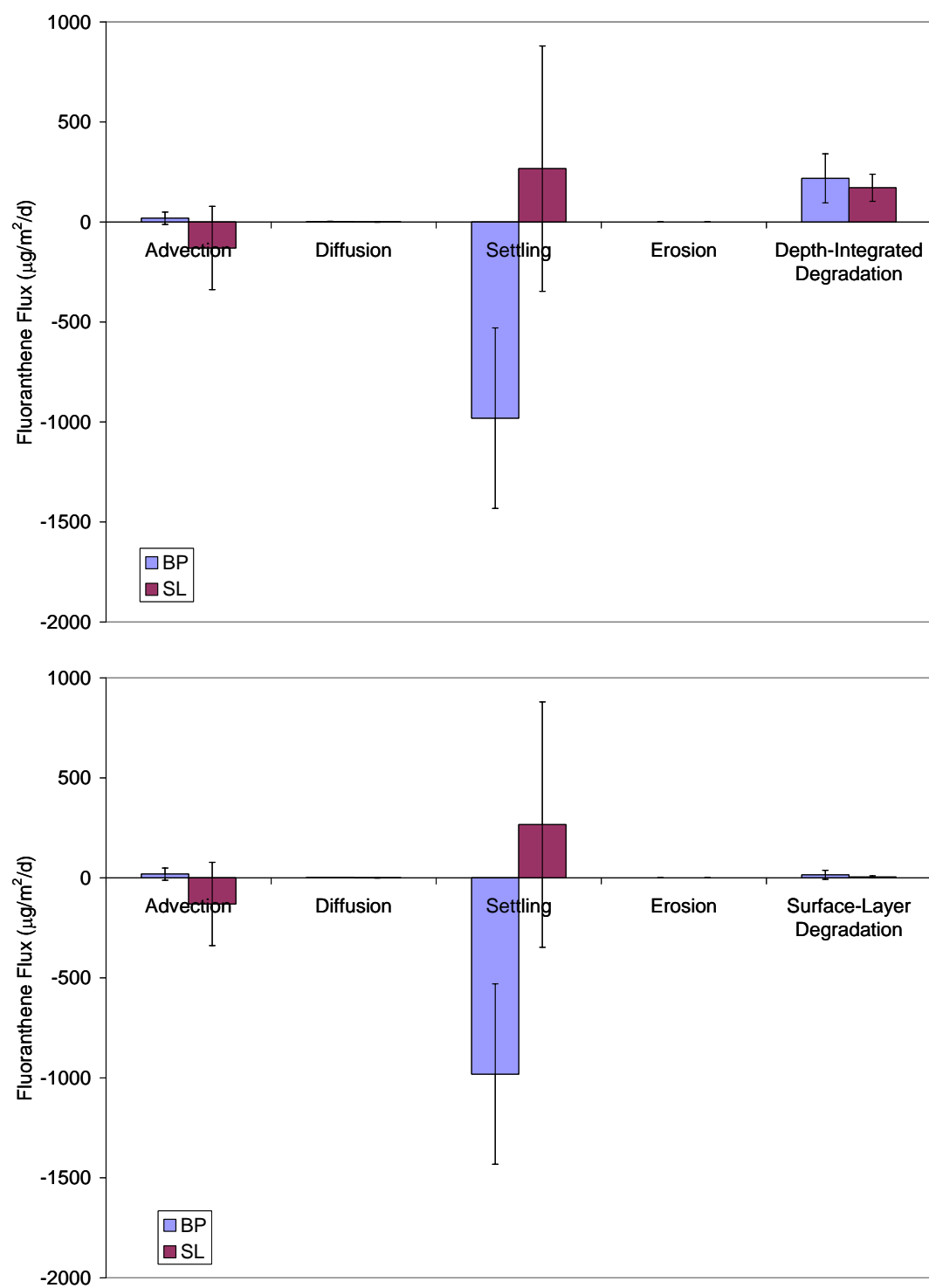


Figure 7-21. PRISM pathway fluxes for fluoranthene including comparison for depth-integrated biodegradation (top) and surface-layer biodegradation (bottom).

## 7.8 PATHWAY INTERPRETATION

As shown above, for a given site it is possible to compare the PRSIM pathways directly as flux rates. However, these comparisons lack the context of environmental relevance since a relatively large flux for a given pathway relative to other pathways does not imply that the pathway is important from the standpoint of risk or remedy selection. Some additional insight can be gained into this relevance by normalizing the terms to a scale that is relevant to risk reduction or recovery for the site. The risk/recovery level could be based on any number of criteria including water quality standards, sediment quality standards, or site specific cleanup levels (for either sediment or porewater). An equivalent time scale can also be adopted for the site based on a target recovery times or exposure durations. For example, a desired recovery rate (with the same dimension as our fluxes) can be defined as

$$R_R = \frac{\Delta m}{\Delta t} = \frac{(c - c_C)H}{t_R}$$

where  $c$  is the current concentration in the sediment,  $c_C$  is the target level for cleanup or risk reduction and  $t_R$  is the target recovery time scale. Normalizing all flux terms to  $R_R$  results in a set of indices that reflect the relative contribution of various transport processes to site recovery or risk.

$$\begin{aligned} I_{DC} &= \frac{F_{DC}}{R_R} && \text{diffusion index} \\ I_{DS} &= \frac{F_{DB}}{R_R} && \text{bioirrigation index} \\ I_A &= \frac{w(c_0 - c_H)}{R_R} && \text{advection index} \\ I_B &= \frac{R_B H}{R_R} && \text{biodegradation index} \\ I_E &= \frac{K_E(\tau - \tau_c)c_B}{R_R} && \text{erosion index} \\ I_S &= \frac{S(c_B - c_S)}{R_R} && \text{sedimentation index} \end{aligned}$$

These indices then provide one non-dimensional yardstick for pathway ranking of important processes that can influence the fate and exposure of in-place sediment contamination. The interpretation of these indices would be that the larger indices are the more dominant pathways, and that pathways with  $I \geq 1$  or greater could represent an important process for recovery (or exposure).

Of course, there are substantial uncertainties in predicting long-term (years to decades) contaminant behavior based upon short-term (minutes to months) measurements. Furthermore,

there are clear problems in examining or predicting changes over time from equations developed assuming steady state. For example, there is no doubt that PAH degradation rates vary substantially as concentration, nutrient level, temperature, and other factors vary. Thus, a measurement of instantaneous mineralization rates, while predictive of recovery times if all things remained constant, will not actually predict how long actual recovery of sediments would take by biodegradation or how far that process will go. Parallel arguments can be made for all of the processes being discussed, since all measurements being made are short-term measurements (e.g., the SPI measurements are instantaneous snapshots, seep and BFSD are measured for ~72 hours, flume measurements for a few hours at the most). It should be pointed out that these indices are only one way in which results can be applied to site management. Either all or a portion of the results can be used to refine Conceptual Site Models (CSMs), and specific data can be inserted into other models used to predict contaminant fate in terms of either risk or recovery.

### **Recovery Indices**

As an example application for the PRISM pathway fluxes, we calculated recovery indices for each of the pathways. The normalizing recovery rate was estimated using the measured concentration in the mixed layer for  $c$ , the ERM for that chemical for  $c_e$ , and a recovery time of ten years for  $t_R$ . Note that these are just examples, and that site-specific PRGs or other thresholds could be used in place of ERMs, and that the time scale of ten years could be varied depending on management goals. Figure 7-22 shows the stacked ERM and ERL hazard quotients (ERM HQs and ERL HQs) for bulk surface (H), deep (H-) and trap sediments. Note that no ERM is available for Mn, so it is not listed in figures. ERM HQs are calculated by dividing the mean sediment COPC concentration by the ERM. If the ERM is greater than one, the ERM is exceeded. These values help put sediment values in perspective, by demonstrating which contaminants may “drive” risk or management at a site, for surface, deep and settling sediments. Indices were only calculated for those chemicals for which the mixed layer concentration exceeded the ERM. For metals these included copper, nickel and zinc. Based on this analysis, we found that settling appears to be a significant pathway for recovery at Bishop Point for copper and zinc (Figure 7-23 and Figure 7-25). For nickel, recovery by settling is weaker but is supplemented by diffusion (Figure 7-24). However, both of these processes appear to be offset by a continuing source from advection. For Southeast Loch, settling continues to act as a source for copper and zinc to the extent that no other process is dominant enough to drive recovery for these metals. For nickel, potential recovery via settling and diffusion appears to be balanced by a continuing source from advection.

For PAHs, mixed layer concentrations were already near or below ERMs for the three target PAHs, thus PRISM fluxes were normalized to recovery rates calculated from ERLs. Both phenanthrene and fluoranthene had mixed layer concentrations exceeding the ERL. Based on the indices developed from these recovery rates, biodegradation appears to be a key process controlling recovery of phenanthrene at both sites (Figure 7-26). At Bishop Point, the loss due to biodegradation is balanced by an ongoing source of similar magnitude from settling. At Southeast Loch, the settling source is small relative to depth-integrated biodegradation. However, if we assume aerobic biodegradation of phenanthrene is only active in the surface layer, then the ongoing source from settling at Bishop Point would overwhelm any recovery process. For fluoranthene, depth-integrated degradation was still the dominant recovery mechanism at Bishop Point, however, the magnitude of the index was  $<1$ , and the settling flux

for fluoranthene represents a significant ongoing source at Bishop Point relative to all recovery processes (Figure 7-27). For Southeast Loch, both settling and biodegradation represent significant recovery processes. However, these processes appear to be balanced to a lesser degree by an advective source.

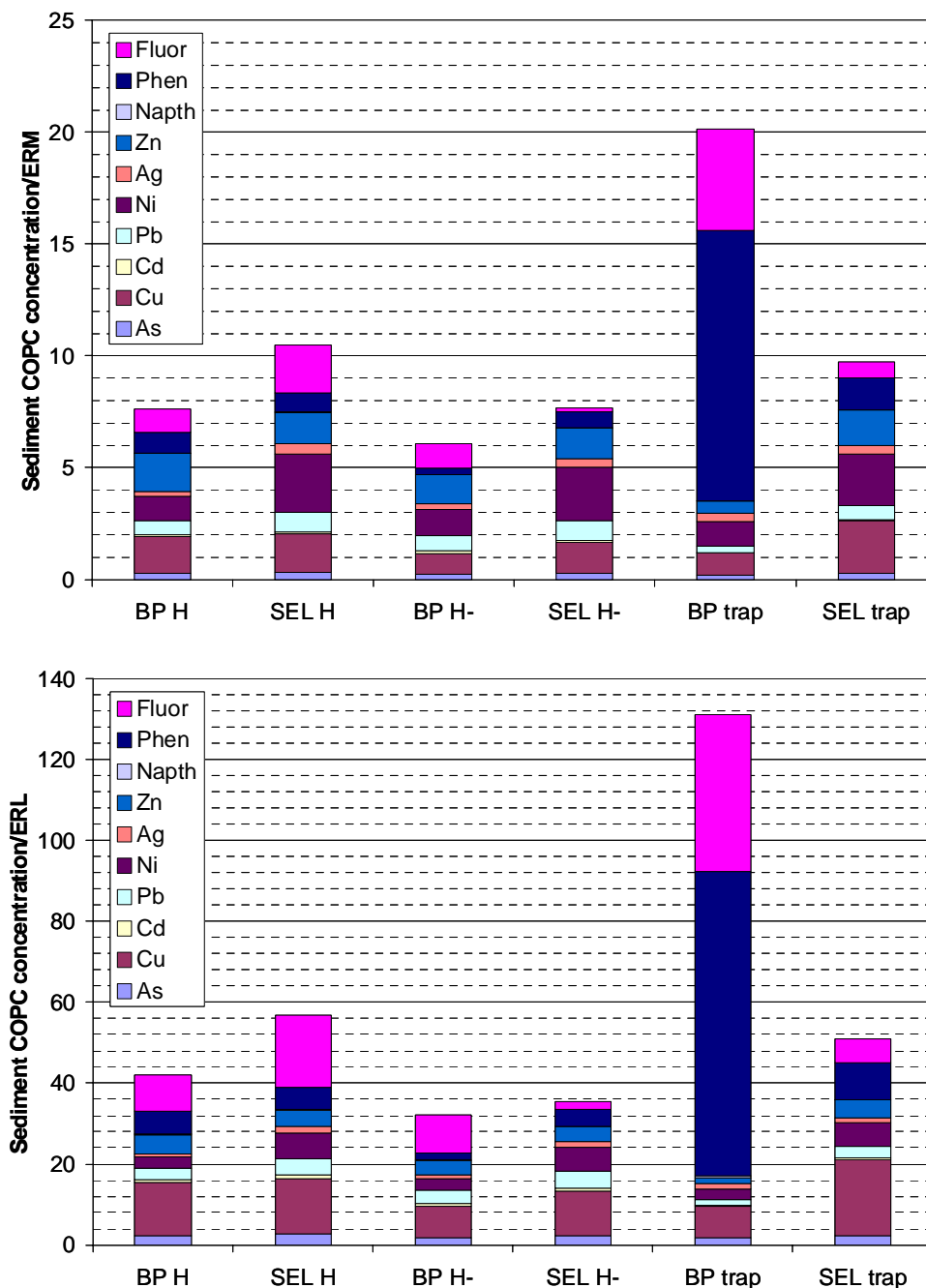


Figure 7-22. Stacked ERM HQ and ERL HQ values for BP and SEL surface, deep and trap sediments.

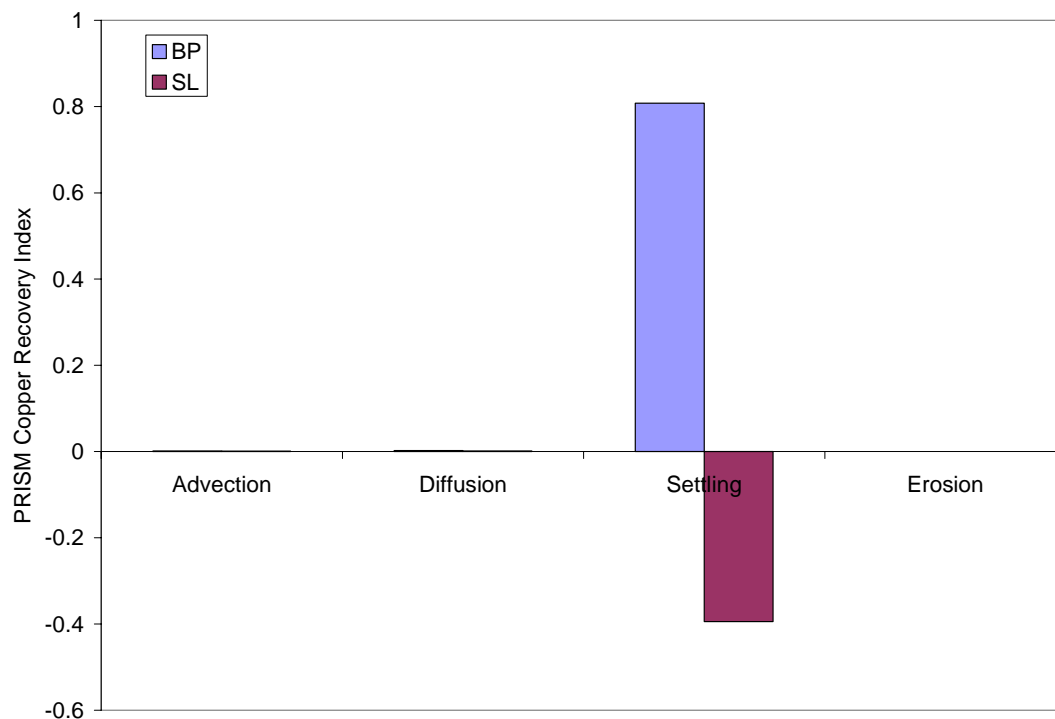


Figure 7-23. Recovery rate normalized pathway index for copper at Bishop Point and Southeast Loch.

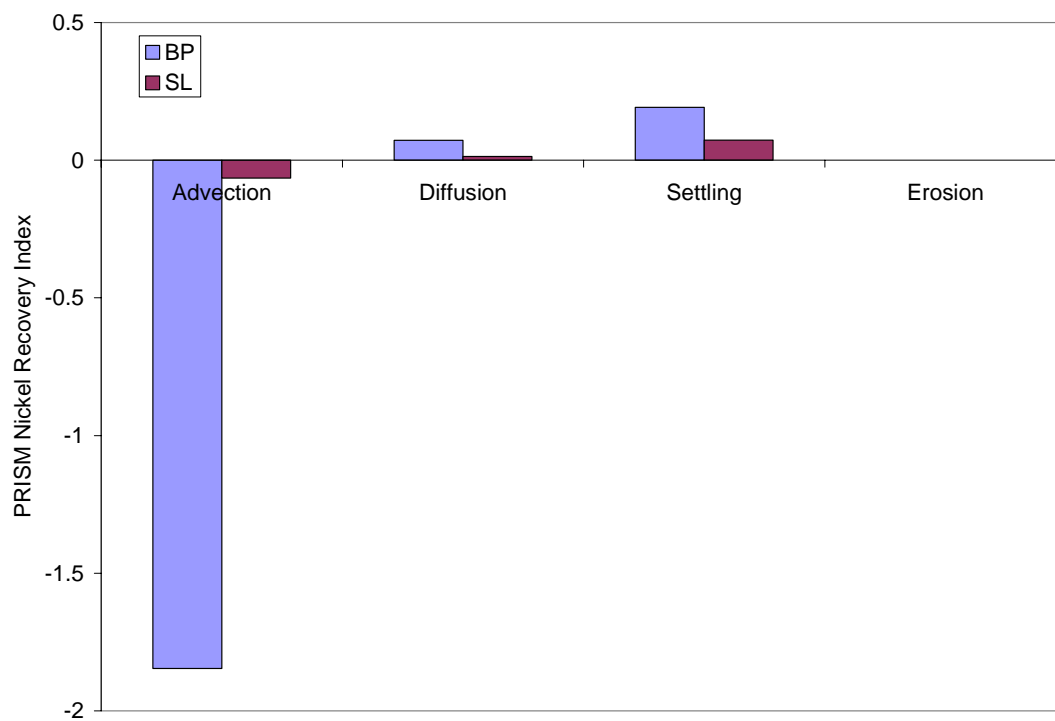


Figure 7-24. Recovery rate normalized pathway index for nickel at Bishop Point and Southeast Loch.



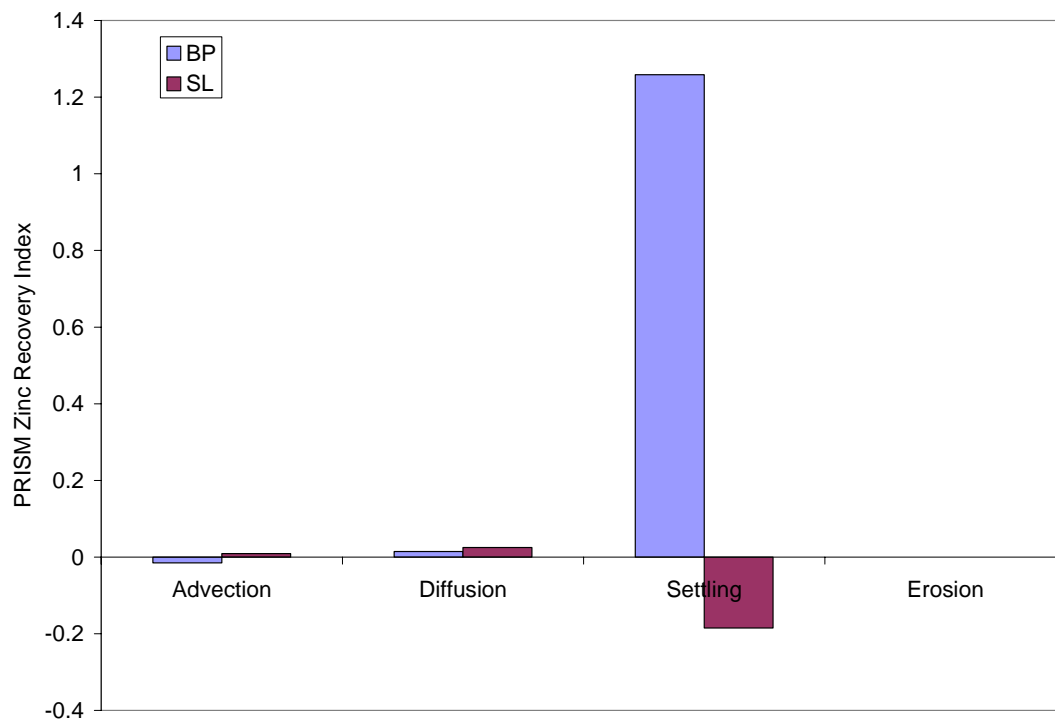


Figure 7-25. Recovery rate normalized pathway index for zinc at Bishop Point and Southeast Loch.

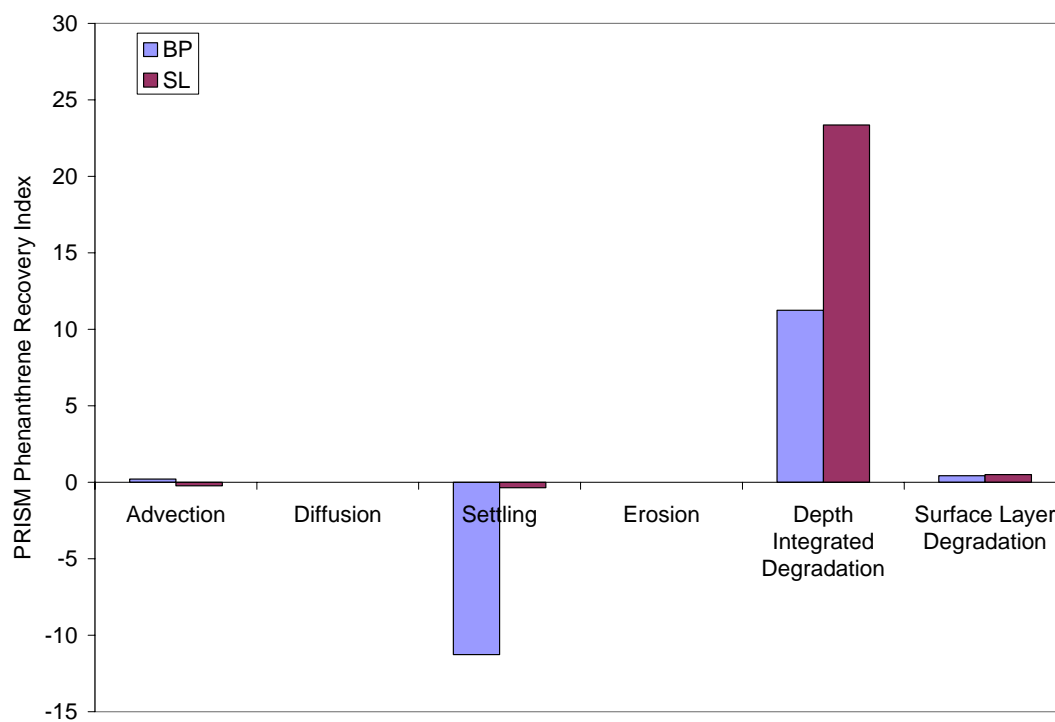


Figure 7-26. Recovery rate normalized pathway index for phenanthrene at Bishop Point and Southeast Loch.

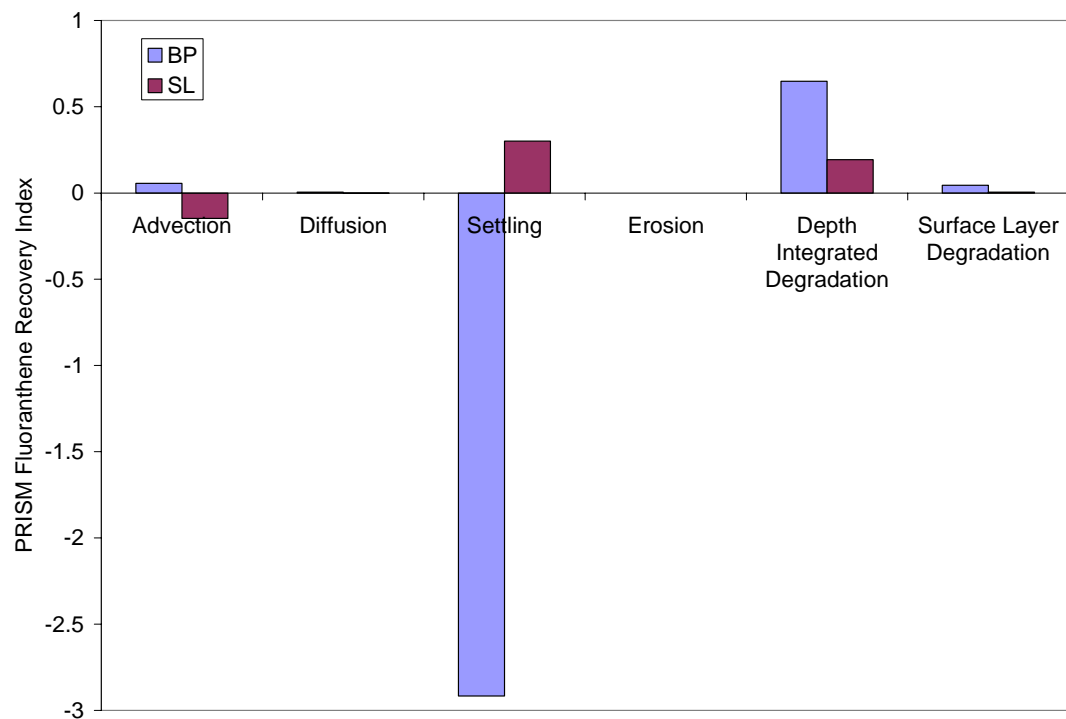


Figure 7-27. Recovery rate normalized pathway index for fluoranthene at Bishop Point and Southeast Loch.

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## **8 Summary**

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The objective of this program was to provide an understanding of the relative importance of critical contaminant transport pathways for near-shore in-place sediments in the risk, fate and management of contaminated sediments via: 1) An integrated suite of measurement techniques to characterize and quantify important transport pathways for in-place sediments, 2) A corresponding set of indices that quantify the transport phenomenon on a common dimensional scale and 3) Field scale evaluation of the effectiveness of the measurement tools and the importance of quantified transport pathways.

The program was successful in fielding the measurement suite, and quantifying a range of process-based transport pathways including:

- Diffusive Fluxes (combined molecular and bio)
- Advective Fluxes
- Sedimentation Fluxes
- Erosion Fluxes
- Biodegradation Fluxes

The maturity and reliability of the individual field tools was assessed. Technology maturity generally ranged from commercial-off-the-shelf (current meters, particle sizing, SPI) to published (flumes). Methodologies generally ranged from published (seepage meters, microprofilers) to certified (BFSD) to standard (porewater chemistry). Although some failures were encountered, most of the technologies were found to operate reliably for the application to PRISM pathways. Notable exceptions were the age-dated coring at Southeast Loch, where recent dredging operations confounded the interpretation of the historical record, and the bio-inhibited BFSD measurements, which were unsuccessful due to difficulties in gauging the oxygen uptake rate.

The PRISM pathway analysis for metals in Pearl Harbor was carried out by comparing the raw flux rates associated with each pathway. The analysis provides a means of evaluating which pathways may be dominant for the given site where the measurements were conducted. The analysis revealed that, in general, deposition at the Bishop Point site is driving a reduction in metals levels in the mixed layer, while deposition at Southeast Loch represents a potential source of some metals to the mixed layer including copper and zinc. Other processes play an active role in the fate and transport of individual metals, particularly advection and diffusion with respect to arsenic, cadmium and nickel. We also calculated recovery indices for selected metals for each of the PRISM pathways. Indices were only calculated for those metals for which the mixed layer concentration exceeded the ERM, including copper, nickel and zinc. Based on this analysis, we found that settling appears to be a significant pathway for recovery at Bishop Point for copper and zinc. For nickel, recovery by settling is weaker but is supplemented by diffusion. However, both of these processes appear to be offset by a continuing source from advection. For Southeast Loch, settling continues to act as a source for copper and zinc to the extent that no other process is dominant enough to drive recovery for these metals. For nickel at Southeast Loch, potential recovery via settling and diffusion appears to be balanced by a continuing source from advection.

The PRISM pathway analysis for PAHs in Pearl Harbor was carried out by comparing the raw flux rates associated with each pathway. The analysis indicated that, in general, settling

represents an ongoing source of PAHs to the mixed layer sediments of Bishop Point. This source appears to be offset by a high biodegradation potential, especially for the lower molecular weight PAHs such as naphthalene and phenanthrene. In contrast, settling does not appear to be a dominant source at Southeast Loch, and in some cases (fluoranthene) represents a loss of PAHs from the mixed layer. Advection may be acting as a source for some PAHs at Southeast Loch, although this is offset to some degree by biodegradation. We also calculated recovery indices for selected PAHs for each of the PRISM pathways. Indices were only calculated for those PAHs for which biodegradation rates were available, and for which the mixed layer concentration exceeded the ERL, including phenanthrene and fluoranthene. Based on the indices developed from these recovery rates, biodegradation appears to be a key process controlling recovery of phenanthrene at both sites. At Bishop Point, the loss due to biodegradation is balanced by an ongoing source of similar magnitude from settling. At Southeast Loch, the settling source is small relative to depth-integrated biodegradation. However, if we assume aerobic biodegradation of phenanthrene is only active in the surface layer, then the ongoing source from settling at Bishop Point would overwhelm any recovery process. For fluoranthene, depth-integrated degradation was still the dominant recovery mechanism at Bishop Point, however, the magnitude of the index was  $<1$ , and the settling flux for fluoranthene represents a significant ongoing source at Bishop Point relative to all recovery processes. For Southeast Loch, both settling and biodegradation represent significant recovery processes. However, these processes appear to be balanced to a lesser degree by an advective source.

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## 9 References

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## **Site 2 – Pearl Harbor Data Appendix**

**GENERAL CHEMISTRY**

**GEOCHEMISTRY**

**CHRONO TRACER CHEMISTRY**

**MAJOR ELEMENT CHEMISTRY**

**SPI IMAGES**

**HYDRODYNAMIC CURRENTS**

**FLUME DATA**

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**BATTELLE MARINE SCIENCES LABORATORY**  
**1529 W. Sequim Bay Road**  
**Sequim, WA 98382**  
**(360) 683-4151**

(cf#1939)		direct	direct	Fe/Pd	direct
MSL	Sponsor	Al	Fe	Cr	Mn
Code	Rep I.D.	ICP-MS	ICP-MS	ICP-MS	ICP-MS
<b>SAMPLE RESULTS</b>					
1939*41	BPA-cpsw-metals	5.19 J	1070	0.208 BJ	3.21
1939*42	BPB-cpsw-metals	19.5 J	1060	0.198 BJ	1.86
1939*43	BPC-cpsw-metals	6.12 J	1130	0.180 BJ	2.17
1939*44	SLA-cpsw-metals	3.72 J	1110	0.177 BJ	8.32
1939*45	SLB-cpsw-metals	8.38 J	1110	0.145 BJ	1.64
1939*46	SLC-cpsw-metals	5.13 J	1160	0.173 BJ	5.30
1939*47	BPA-cppw-metals-U	5.29 J	1740	0.263 BJ	150
1939*48	BPB-cppw-metals-U	7.61 J	1700	0.243 BJ	160
1939*49	BPC-cppw-metals-U	6.84 J	1740	0.237 BJ	219
1939*50	BPA-cppw-metals-L	5.44 J	1940	0.566 BJ	15.1
1939*51	BPB-cppw-metals-L	29.3 J	1470	0.455 BJ	80.5
1939*52	BPC-cppw-metals-L	4.04 J	1690	0.347 BJ	111
1939*53	SLA-cppw-metals-U	4.75 J	1800	3.08	308
1939*54	SLB-cppw-metals-U	8.83 J	1830	0.341 BJ	847
1939*55	SLC-cppw-metals-U	2.36 U	1780	0.347 BJ	484
1939*56	SLA-cppw-metals-L	4.96 J	1570	0.423 BJ	26.9
1939*57	SLB-cppw-metals-L	5.36 J	1570	0.380 BJ	233
1939*58	SLC-cppw-metals-L	5.95 J	1360	0.414 BJ	24.7
1939*59	BPC-BFSD1-D1-Metals	57.6	1930	0.385 BJ	3.83
1939*60	BPC-BFSD1-D2-Metals	41.0 J	2050	0.456 BJ	12.9
1939*61	BPC-BFSD1-D3-Metals	12.7 J	1920	0.343 BJ	10.7
1939*62	BPC-BFSD1-D4-Metals	7.90 J	1980	0.375 BJ	8.56
1939*63	BPC-BFSD1-D5-Metals	9.04 J	1930	0.363 BJ	10.0
1939*64	BPA-SMA2-Comp456-Metals	17.6 J	1990	0.770 BJ	255
1939*65	SLA-SMA-1-Metals	524	2380	2.35	367
1939*66	SLA-SMA-2-Metals	501	2420	1.99	404

1939*67	SLA-SMA-3-Metals	478	2480	2.10	418
1939*68	SLA-SMA-Comp45-Metals	271	2240	1.15	333
1939*69	SLA-SMA-6-Metals	333	2400	1.30	357
1939*70	SLB-SMB-2-Metals	86.8	1980	0.658 BJ	215
1939*71	SLB-SMB-3-Metals	62.2	2040	0.483 BJ	322
1939*72	SLB-SMB-Comp45-Metals	33.5 J	1930	0.419 BJ	645
1939*73	SLB-SMB-6-Metals	25.9 J	2120	0.683 BJ	970
1939*74	SLB-BFSD1-D6-Metals	40.6 J	2000	0.492 BJ	8.18
1939*75	SLB-BFSD1-D7-Metals	27.0 J	2000	0.466 BJ	12.1
1939*76	SLB-BFSD1-D8-Metals	7.78 J	1970	0.324 BJ	13.9
1939*77	SLB-BFSD1-D9-Metals	7.31 J	2050	0.521 BJ	17.3
1939*78	SLB-BFSD1-D10-Metals	6.24 J	1960	0.331 BJ	43.9
1939*79	BPA-BFSD-G1-Metals	4.33 J	2000	0.325 BJ	4.59
1939*80	BPA-BFSD-G2-Metals	6.14 J	2050	0.599 BJ	50.9
1939*81	BPA-BFSD-G3-Metals	6.77 J	2120	0.512 BJ	75.9
1939*82	BPA-BFSD-G4-Metals	7.09 J	2100	0.386 BJ	86.0
1939*83	BPA-BFSD-G5-Metals	8.18 J	2110	0.254 BJ	85.9
1944*13	SLC-BFSD2-B1-Metals	3.57 J	1090	0.406 BJ	3.21
1944*14	SLC-BFSD2-B2-Metals	8.01 J	1080	0.364 BJ	8.30
1944*15	SLC-BFSD2-B3-Metals	5.57 J	1100	0.296 BJ	7.71
1944*16	SLC-BFSD2-B4-Metals	3.14 J	1110	0.252 BJ	11.5
1944*17	SLC-BFSD2-B5-Metals	17.7 J	1140	0.350 BJ	7.35
1944*18	SLC-BFSD2-B6-Metals	7.84 J	1100	0.306 BJ	19.5
1944*19	SLA-BFSD2-B7-Metals	6.77 J	1130	0.373 BJ	3.63
1944*20	SLA-BFSD2-B8-Metals	11.3 J	1250	0.346 BJ	13.7
1944*21	SLA-BFSD2-B9-Metals	6.54 J	1130	0.306 BJ	11.1
1944*22	SLA-BFSD2-B10-Metals	65.1	1230	0.857 BJ	22.8
1944*23	SLA-BFSD2-B11-Metals	2.36 U	1200	0.290 BJ	16.0
1944*24	SLA-BFSD2-B12-Metals	6.33 J	1130	0.294 BJ	17.5

**PROCEDURAL BLANK**

2.36 U	2.46 U	0.100 J	0.31
2.36 U	2.46 U	0.232 J	0.31
2.36 U	2.46 U	0.287 J	0.31
2.36 U	2.46 U	0.112 J	0.31
NA	NA	0.315 J	NA
2.36 U	2.46 U	0.209 BJ	0.31

<b>METHOD DETECTION LIMIT</b>			<b>2.36</b>	<b>2.46 ~</b>	<b>0.031</b>	<b>0.31</b>
<b>Project Target Detection Limit</b>			<b>50.0</b>	<b>10.0</b>	<b>1.00</b>	<b>0.50</b>
<b>STANDARD REFERENCE MATERIAL</b>						
1640			55.9	37.5	38.2	122
1640			52.5	52.7	37.8	120
			55.0	46.8	39.2	115
			48.7 J	42.4	38.8	122
1640	certified value		52.0	34.3	38.6	122
1640	range		±1.5	±1.6	±1.6	±1.1
	% difference		8%	9%	1%	0%
	% difference		1%	54% e	2%	1%
			6%	36% e	2%	5%
			6%	24% e	1%	0%
CASS-4	Dissolved		NA	NA	0.243 BJ	NA
CASS-4	Dissolved		NA	NA	0.338 BJ	NA
CASS-4	Dissolved		NA	NA	0.433 BJ	NA
CASS-4	Dissolved		NA	NA	0.312 BJ	NA
CASS-4	Dissolved		NA	NA	0.502 BJ	NA
CASS-4	certified value		NC	0.71 U	0.144 BJ	2.78
CASS-4	range		NC	±0.058	±0.029	±0.19
	% difference		N/A	N/A	69% e	N/A
	% difference		N/A	N/A	135% e	N/A
	% difference		N/A	N/A	201% e	N/A
	% difference		N/A	N/A	117% e	N/A
	% difference		N/A	N/A	249% e	N/A
<b>STANDARD REFERENCE MATERIAL, cont.</b>						
1641d	Dissolved		NA	NA	NA	NA
1641d	Dissolved		NA	NA	NA	NA

1641d	Dissolved	NA	NA	NA	NA
1641d	Dissolved	NA	NA	NA	NA
1641d	Dissolved	NA	NA	NA	NA
1641d	certified value	NC	NC	NC	NC
1641d	range	NC	NC	NC	NC
	% difference	N/A	N/A	N/A	N/A
	% difference	N/A	N/A	N/A	N/A
	% difference	N/A	N/A	N/A	N/A
	% difference	N/A	N/A	N/A	N/A
	% difference	N/A	N/A	N/A	N/A

#### ICV,CCV RESULTS

ICV	99%	101%	104%	104%
CCV	118% #	82% #	99%	105%
CCV	115%	85%	101%	107%
CCV	NA	NA	101%	NA
CCV	NA	NA	99%	NA
CCV	NA	NA	NA	NA

ICV	102%	100%	101%	102%
CCV	97%	105%	103%	104%
CCV	99%	111%	101%	102%
CCV	104%	101%	98%	99%
CCV	111%	94%	97%	98%
CCV	116% #	99%	98%	99%
CCV	112%	87%	NA	99%
CCV	112%	86%	NA	99%
CCV	97%	97%	NA	102%
CCV	119% #	105%	NA	101%

ICV	110%	89%	102%	106%
CCV	122% #	87%	101%	107%
CCV	116% #	85%	99%	107%
CCV	118% #	82% #	NA	105%
CCV	NA	NA	NA	NA



ICV	NA	NA	101%	NA
CCV	NA	NA	101%	NA
CCV	NA	NA	98%	NA
CCV	NA	NA	100%	NA
CCV	NA	NA	NA	NA
ICV	NA	NA	NA	NA
CCV	NA	NA	NA	NA
CCV	NA	NA	NA	NA
CCV	NA	NA	NA	NA

#### BLANK SPIKE RESULTS

Amount Spiked	25.0 J	100	25.0	25.0
Blank 1	2.36 U	2.46 U	0.100 BJ	0.31
Blank 1 + Spike	30.0 J	82.8	23.1	27.1
Amount Recovered	30.0 J	82.8	23.0	27.1
<b>Percent Recovery</b>	<b>120%</b>	<b>83%</b>	<b>92%</b>	<b>108%</b>
Amount Spiked	25.0 J	100	25.0	25.0
Blank 2	2.36 U	2.46 U	0.260 BJ	0.31
Blank 2 + Spike	28.5 J	105	23.4	27.8
Amount Recovered	28.5 J	105	23.1	27.8
<b>Percent Recovery</b>	<b>114%</b>	<b>105%</b>	<b>92%</b>	<b>111%</b>
Amount Spiked	25.0 J	100	25.0	25.0
Blank 3	2.36 U	2.46 U	0.260 BJ	0.31
Blank 3 + Spike	28.4 J	105	24.5	28.1
Amount Recovered	28.4 J	105	24.2	28.1
<b>Percent Recovery</b>	<b>114%</b>	<b>105%</b>	<b>97%</b>	<b>112%</b>
Amount Spiked	25.0 J	100	25.0	25.0
Blank 4	2.36 U	2.46 U	0.312 BJ	0.31
Blank 4 + Spike	30.0 J	82.8	21.1	27.1
Amount Recovered	30.0 J	82.8	20.8	27.1
<b>Percent Recovery</b>	<b>120%</b>	<b>83%</b>	<b>83%</b>	<b>108%</b>

Amount Spiked	NS	NS	25.0	NS
Blank 5	N/A	N/A	0.315 BJ	N/A
Blank 5 + Spike	NS	NS	23.5	NS
Amount Recovered	N/A	N/A	23.2	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>93%</b>	<b>N/A</b>

#### MATRIX SPIKE RESULTS

Amount Spiked	100	1000	25.0	100
1939*42	18.8 J	955	0.198 BJ	1.88
1939*42 + Spike	119	1760	21.0	111
Amount Recovered	100	805	20.8	109
<b>Percent Recovery</b>	<b>100%</b>	<b>81%</b>	<b>83%</b>	<b>109%</b>

Amount Spiked	NS	NS	NS	NS
1939*43	N/A	N/A	N/A	N/A
1939*43 + Spike	NS	NS	NS	NS
Amount Recovered	N/A	N/A	N/A	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>

Amount Spiked	25.0 J	100	NS	100
1939*47	4.65 J	1730	N/A	150
1939*47 + Spike	33.6 J	1800	NS	255
Amount Recovered	29.0 J	70.0	N/A	105
<b>Percent Recovery</b>	<b>116%</b>	<b>70%</b>	<b>N/A</b>	<b>105%</b>

Amount Spiked	NS	NS	20.0	NS
1939*53	N/A	N/A	3.08	N/A
1939*53 + Spike	NS	NS	26.9	NS
Amount Recovered	N/A	N/A	23.8	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>119%</b>	<b>N/A</b>

Amount Spiked	NS	NS	NS	NS
1939*63	N/A	N/A	N/A	N/A
1939*63 + Spike	NS	NS	NS	NS
Amount Recovered	N/A	N/A	N/A	N/A

<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
Amount Spiked	100	100	25.0	100
1939*65	528	2400	2.35	367
1939*65+ Spike	658	2550	28.5	476
Amount Recovered	130	150	26.2	109
<b>Percent Recovery</b>	<b>130%</b>	<b>150%</b>	<b>105%</b>	<b>109%</b>
Amount Spiked	NS	NS	NS	NS
1939*70	N/A	N/A	N/A	N/A
1939*70+ Spike	NS	NS	NS	NS
Amount Recovered	N/A	N/A	N/A	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
Amount Spiked	100	100	NS	25.0
1939*79	4.21 J	2010	N/A	4.72
1939*79+ Spike	123	2200	NS	32.8
Amount Recovered	119	190	N/A	28.1
<b>Percent Recovery</b>	<b>119%</b>	<b>190% w</b>	<b>N/A</b>	<b>112%</b>
Amount Spiked	NS	NS	25.0	NS
1939*81	N/A	N/A	0.512 BJ	N/A
1939*81 + Spike	NS	NS	24.2	NS
Amount Recovered	N/A	N/A	23.7	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>95%</b>	<b>N/A</b>
Amount Spiked	NS	NS	NS	NS
1939*82	N/A	N/A	N/A	N/A
1939*82 + Spike	NS	NS	NS	NS
Amount Recovered	N/A	N/A	N/A	N/A
<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
Amount Spiked	NS	NS	NS	NS
1944*14	N/A	N/A	N/A	N/A
1944*14 + Spike	NS	NS	NS	NS
Amount Recovered	N/A	N/A	N/A	N/A

		<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
		Amount Spiked	NS	NS	25.0	NS
		1944*15	N/A	N/A	0.296 BJ	N/A
		1944*15 + Spike	NS	NS	25.8	NS
		Amount Recovered	N/A	N/A	25.5	N/A
		<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>102%</b>	<b>N/A</b>
		Amount Spiked	NS	NS	NS	NS
		1944*16	N/A	N/A	N/A	N/A
		1944*16 + Spike	NS	NS	NS	NS
		Amount Recovered	N/A	N/A	N/A	N/A
		<b>Percent Recovery</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
		Amount Spiked	100	1000	NS	100
		1944*20	10.5 J	1210	N/A	13.5
		1944*20 + Spike	110	1840	NS	122
		Amount Recovered	99.6	630	N/A	109
		<b>Percent Recovery</b>	<b>100%</b>	<b>63%</b>	<b>N/A</b>	<b>109%</b>
<b>REPLICATE RESULTS</b>						
1939*41		BPA-cpsw-metals	5.19 J	1070	0.208 BJ	3.21
1939*41	2	BPA-cpsw-metals	NA	NA	0.206 BJ	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>
1939*42		BPB-cpsw-metals	19.5 J	1060	0.198 BJ	1.86
1939*42	2	BPB-cpsw-metals	18.1 J	850	NA	NA
		<b>% difference</b>	<b>7%</b>	<b>22%</b>	<b>N/A</b>	<b>N/A</b>
1939*44		SLA-cpsw-metals	3.72 J	1110	0.177 BJ	8.32
1939*44	2	SLA-cpsw-metals	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>

1939*47		BPA-cppw-metals-U	5.29 J	1740	0.263 BJ	150
1939*47	2	BPA-cppw-metals-U	4.01 J	1720	NA	150
		<b>% difference</b>	<b>28%</b>	<b>1%</b>	<b>N/A</b>	<b>0%</b>
1939*48		BPB-cppw-metals-U	7.61 J	1700	0.243 BJ	160
1939*48	2	BPB-cppw-metals-U	NA	NA	0.241 BJ	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>
1939*49		BPC-cppw-metals-U	6.84 J	1740	0.237 BJ	219
1939*49	2	BPC-cppw-metals-U	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1939*62		BPC-BFSD1-D4-Metals	7.90 J	1980	0.375 BJ	8.56
1939*62	2	BPC-BFSD1-D4-Metals	NA	NA	0.466 BJ	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>22%</b>	<b>N/A</b>
1939*65		SLA-SMA-1-Metals	524	2380	2.35 BJ	367
1939*65	2	SLA-SMA-1-Metals	532	2420	NA	366
		<b>% difference</b>	<b>2%</b>	<b>2%</b>	<b>N/A</b>	<b>0%</b>
1939*69		SLA-SMA-6-Metals	333	2400	1.30 BJ	357
1939*69		SLA-SMA-6-Metals	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1939*79		BPA-BFSD-G1-Metals	4.33 J	2000	0.325 BJ	4.59
1939*79	2	BPA-BFSD-G1-Metals	4.08 J	2020	0.327 BJ	4.84
		<b>% difference</b>	<b>6%</b>	<b>1%</b>	<b>1%</b>	<b>5%</b>
1939*80		BPA-BFSD-G2-Metals	6.14 J	2050	0.599 BJ	50.9

1939*80	2	BPA-BFSD-G2-Metals	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1939*83		BPA-BFSD-G5-Metals	8.18 J	2110	0.254 BJ	85.9
1939*83	2	BPA-BFSD-G5-Metals	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1944*13		SLC-BFSD2-B1-Metals	3.57 J	1090	0.406 BJ	3.21
1944*13	2	SLC-BFSD2-B1-Metals	NA	NA	0.401 BJ	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>
1944*19		SLC-BFSD2-B7-Metals	6.77 J	1130	0.373 BJ	3.63
1944*19	2	SLC-BFSD2-B7-Metals	NA	NA	NA	NA
		<b>% difference</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1944*20		SLC-BFSD2-B8-Metals	11.3 J	1250	0.346 BJ	13.7
1944*20	2	SLC-BFSD2-B8-Metals	9.59 J	1170	NA	13.3
		<b>% difference</b>	<b>16%</b>	<b>7%</b>	<b>N/A</b>	<b>3%</b>

---

U = not detected at or above detection limit.

NC = not certified.

NA = not analyzed or available.

N/A = not applicable.

B = Sample results are less than 5 x the blank.

J = result less than the TDL, but more than the MDL.

~ = MDL not available; used average IDL from all runs.

\* = duplicate is out of control.

e = SRM recovery is out of control.

w = spike recovery is out of control due to inappropriate spiking level.

# = continuing calibration recovered outside of acceptable method criteria.

6/20/2006

## SPAWAR PRISM

## CONCENTRATIONS OF METALS IN SEAWATER SAMPLES

Samples Received: 12/13/02-1/03/03

(concentrations in µg/L - not blank corrected)

Fe/Pd	Fe/Pd			Fe/Pd	Fe/Pd	direct	Fe/Pd	
Cu	Zn	As	Se	Ag	Cd	Sn	Pb	Hg
ICP-MS	ICP-MS	FIAS	FIAS	GFAA	ICP-MS	ICP-MS	ICP-MS	CVAF
1.17	7.20	1.47	0.0749 J	0.0142 BJ	0.0405 J	0.0947 J	0.163	0.00100 J
1.03	3.68	1.34	0.063 U	0.0141 BJ	0.0277 J	0.103 J	0.152	0.00126 J
1.28	3.25	1.35	0.0825 J	0.0132 BJ	0.0362 J	0.0877 J	0.275	0.00134 J
1.19	5.17	1.70	0.063 U	0.0157 BJ	0.0311 J	0.0784 J	0.0589 B	0.00114 J
1.65	3.64	1.24	0.0888 J	0.0181 BJ	0.0353 J	0.0624 J	0.0341 BJ	0.000957 J
1.51	9.44	1.34	0.0745 J	0.0154 BJ	0.0338 J	0.0694 J	0.0638 B	0.000941 J
0.546 B	32.8	3.45	0.683	0.0178 BJ	0.0510	0.608	0.238	0.00507 J
3.40	19.9	3.00	1.56	0.0132 BJ	0.0169 J	0.829	0.186	0.0126
1.40	23.3	3.16	1.43	0.013 U	0.0194 J	0.908	0.183	0.0162
0.328 B	16.5	2.80	0.407	0.013 U	0.0184 J	0.926	0.132	0.0136
3.12	36.9	5.76	0.433	0.013 U	0.0319 J	1.04	0.341	0.00792 J
0.860	37.0	4.22	0.452	0.013 U	0.0460 J	0.997	0.317	0.0114
0.948	15.6	3.64	0.336	0.013 U	0.0864	0.489 J	0.318	0.00503 J
0.777	17.7	2.50	0.126 J	0.013 U	0.0155 J	0.533	0.131	0.00370 J
0.676 B	35.6	3.00	0.123 J	0.0154 BJ	0.0243 J	0.416 J	0.198	0.00231 J
0.366 B	8.66	2.74	0.610	0.013 U	0.014 U	0.469 J	0.540	0.00581 J
0.474 B	16.6	3.22	0.125 J	0.013 U	0.0355 J	0.542	0.186	0.00348 J
0.391 B	31.7	1.54	0.117 J	0.013 U	0.0346 J	0.652	0.301	0.00234 J
0.856	3.25	1.12	0.063 U	0.0181 BJ	0.0393 J	0.664	0.0804 B	0.00463 J
1.21	4.93	1.35	0.0714 J	0.0280 BJ	0.0523	0.409 J	0.681	0.00577 J
1.55	5.37	1.43	0.063 U	0.0306 BJ	0.0469 J	0.611	0.360	0.00360 J
2.41	7.52	1.47	0.063 U	0.0374 BJ	0.0287 J	0.585	0.724	0.00388 J
2.03	7.77	1.53	0.063 U	0.0463 BJ	0.0556	0.605	0.785	0.00414 J
1.77	18.0	2.18	0.063 U	0.0336 BJ	0.0167 J	0.380 J	0.334	0.00819 J
6.17	12.7	2.86	0.123 J	0.0219 BJ	0.0156 J	0.659	2.07	0.0172
5.42	9.27	2.67	0.063 U	0.0296 BJ	0.0277 J	0.930	1.74	0.0195

5.24	10.6	2.60	0.063 U	0.0151 BJ	0.0188 J	1.08	1.91	0.0152
3.54	15.3	2.38	0.063 U	0.0203 BJ	0.0249 J	1.30	1.05	0.00922 J
3.47	7.19	2.66	0.0714 J	0.0267 BJ	0.014 U	0.767	1.11	0.00857 J
3.43	9.86	2.60	0.063 U	0.0205 BJ	0.0253 J	0.961	0.449	0.00438 J
2.92	7.69	2.79	0.0683 J	0.0237 BJ	0.0192 J	0.609	0.326	0.00510 J
3.01	11.0	3.41	0.0658 J	0.013 U	0.0181 J	0.518	0.277	0.00331 J
3.18	8.44	4.21	0.0738 J	0.013 U	0.0193 J	0.857	0.305	0.00607 J
1.30	3.05	2.38	0.216	0.0348 BJ	0.0171 J	0.809	0.353	0.00699 J
1.13	3.78	1.75	0.0944 J	0.0280 BJ	0.0252 J	0.669	0.517	0.00474 J
1.17	4.51	1.60	0.157 J	0.013 U	0.0752	0.822	0.305	0.00976 J
1.41	6.68	1.74	0.136 J	0.0263 BJ	0.0422 J	0.624	1.59	0.00387 J
1.97	8.45	1.80	0.0744 J	0.013 U	0.0526	0.873	0.521	0.00638 J
1.40	1.80	1.18	0.063 U	0.0269 BJ	0.0346 J	0.679	0.165	0.00340 J
1.26	13.3	1.32	0.063 U	0.0279 BJ	0.0615	0.992	0.214	0.00433 J
1.44	3.28	1.49	0.063 U	0.0495 BJ	0.0233 J	0.823	0.522	0.00527 J
1.69	4.51	1.70	0.0756 J	0.0678 BJ	0.0355 J	0.591	1.28	0.00446 J
1.36	4.05	1.84	0.063 U	0.0557 BJ	0.0176 J	0.718	0.653	0.00381 J
1.09	2.24	1.18	0.063 U	0.013 U	0.0257 J	0.268 J	0.126	0.00572 J
0.724 B	4.91	1.25	0.063 U	0.013 U	0.0212 J	0.150 J	0.192	0.00716 J
0.616 B	3.82	1.31	0.063 U	0.013 U	0.014 U	0.102 J	0.321	0.00312 J
0.623 B	5.06	1.27	0.063 U	0.013 U	0.0398 J	0.0949 J	0.189	0.00380 J
1.15	9.62	1.32	0.063 U	0.013 U	0.0974	0.105 J	0.295	0.00775 J
0.929	9.82	1.53	0.063 U	0.013 U	1.61	0.0954 J	17.9	0.00492 J
0.988	2.56	1.19	0.063 U	0.013 U	0.0239 J	0.0719 J	0.375	0.00443 J
0.624 B	7.37	1.42	0.063 U	0.013 U	0.0270 J	0.152 J	0.670	0.00309 J
0.827	8.61	1.56	0.063 U	0.013 U	0.0451 J	0.0782 J	2.61	0.00412 J
1.42	4.93	2.14	0.063 U	0.013 U	0.0238 J	0.0787 J	0.553	0.00572 J
1.06	8.30	2.09	0.063 U	0.013 U	0.106	0.0816 J	0.327	0.00398 J
0.769	6.88	2.38	0.063 U	0.013 U	0.0304 J	0.105 J	0.326	0.00310 J
0.162	0.225 U	0.050 U	0.063 U	0.0134 J	0.014 U	0.036 U	0.0242 J	0.00019 U
0.142	0.364 J	0.050 U	0.063 U	0.0173 J	0.014 U	0.036 U	0.0256 J	0.00019 U
0.138	0.306 J	0.050 U	0.063 U	0.013 U	0.014 U	0.036 U	0.0157 J	0.00019 U
0.166	0.225 U	0.050 U	0.063 U	0.0243 J	0.014 U	0.036 U	0.0245 J	0.00019 U
0.137	0.226 J	NA	NA	0.013 U	0.014 U	NA	0.0242 J	0.00019 U
0.149 B	0.299 BJ	0.050 U	0.063 U	0.0183 BJ	0.014 U	0.036 U	0.0228 BJ	0.00019 U





NA	NA	NA	NA	NA	NA	NA	NA	1630
NA	NA	NA	NA	NA	NA	NA	NA	1548
NA	NA	NA	NA	NA	NA	NA	NA	1641
NC	NC	NC	NC	NC	NC	NC	NC	1590
NC	NC	NC	NC	NC	NC	NC	NC	±4.00
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3%
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3%
102%	101%	104%	109%	100%	101%	99%	100%	98%
100%	99%	102%	113%	100%	101%	99%	100%	100%
99%	97%	101%	115%	103%	99%	99%	102%	NA
99%	98%	101%	112%	101%	101%	NA	102%	NA
98%	96%	103%	115%	NA	100%	NA	100%	NA
NA	NA	101%	109%	NA	NA	NA	NA	NA
101%	100%	94%	105%	98%	99%	102%	99%	97%
102%	102%	94%	107%	99%	101%	99%	100%	99%
101%	103%	NA	NA	98%	102%	99%	98%	95%
99%	100%	NA	NA	97%	100%	103%	96%	94%
98%	99%	NA	NA	92%	99%	103%	95%	NA
92%	94%	NA	NA	93%	93%	104%	90%	NA
NA	NA	NA	NA	NA	NA	104%	NA	NA
NA	NA	NA	NA	NA	NA	103%	NA	NA
NA	NA	NA	NA	NA	NA	102%	NA	NA
NA	NA	NA	NA	NA	NA	102%	NA	NA
101%	100%	101%	111%	100%	100%	99%	99%	103%
100%	99%	101%	110%	103%	101%	101%	102%	104%
99%	97%	98%	112%	NA	98%	98%	98%	106%
NA	NA	98%	113%	NA	NA	99%	NA	93%
NA	NA	98%	110%	NA	NA	NA	NA	NA

101%	101%	NA	NA	98%	100%	NA	100%	95%
101%	102%	NA	NA	97%	101%	NA	101%	102%
98%	99%	NA	NA	95%	100%	NA	101%	101%
98%	99%	NA	NA	92%	99%	NA	101%	NA
NA	NA	NA	NA	90%	NA	NA	NA	NA
NA	NA	NA	NA	NA	NA	NA	NA	93%
NA	NA	NA	NA	NA	NA	NA	NA	97%
NA	NA	NA	NA	NA	NA	NA	NA	98%
NA	NA	NA	NA	NA	NA	NA	NA	101%
25.0	25.0	5.00	5.00	25.0	25.0	25.0	25.0	0.00505 J
0.162	0.225 U	0.050 U	0.063 U	0.0134 J	0.014 U	0.036 U	0.0242 J	0.000618 J
23.2	24.1	5.09	6.41	22.7	23.0	24.8	21.6	0.00536 J
23.0	24.1	5.09	6.41	22.7	23.0	24.8	21.6	0.00474 J
92%	96%	102%	128%	91%	92%	99%	86%	94%
25.0	25.0	5.00	5.00	25.0	25.0	25.0	25.0	0.00483 J
0.140	0.335 J	0.050 U	0.063 U	0.0173 J	0.014 U	0.036 U	0.0207 J	0.000270 J
23.7	23.5	5.12	6.27	22.4	23.2	26.1	20.9	0.00527 J
23.6	23.2	5.12	6.27	22.4	23.2	26.1	20.9	0.00500 J
94%	93%	102%	125%	90%	93%	104%	84%	104%
25.0	25.0	5.00	5.0	25.0	25.0	25.0	25.0	0.00493 J
0.140	0.335 J	0.050 U	0.063 U	0.0173 J	0.014 U	0.036 U	0.0207 J	0.000609 J
26.2	26.5	4.83	5.32	22.9	25.5	25.9	23.0	0.00575 J
26.1	26.2	4.83	5.32	22.9	25.5	25.9	23.0	0.00514 J
104%	105%	97%	106%	92%	102%	104%	92%	104%
25.0	25.0	5.00	5.00	25.0	25.0	25.0	25.0	0.00978 J
0.749	0.589	0.050 U	0.063 U	0.0243 J	0.0322 J	0.036 U	0.0326 J	0.000302 J
21.8	23.2	4.86	5.65	22.6	22.5	24.8	21.1	0.0101
21.1	22.6	4.86	5.65	22.6	22.5	24.8	21.1	0.00980 J
84%	90%	97%	113%	90%	90%	99%	84%	100%

25.0	25.0	NS	NS	25.0	25.0	NS	25.0	0.00483 J
0.137	0.226 J	N/A	N/A	0.013 U	0.014 U	N/A	0.0242 J	0.000354 J
25.1	25.9	NS	NS	20.1	25.0	NS	23.3	0.00512 J
24.9	25.6	N/A	N/A	20.1	25.0	N/A	23.2	0.00477 J
<b>100%</b>	<b>102%</b>	<b>N/A</b>	<b>N/A</b>	<b>80%</b>	<b>100%</b>	<b>N/A</b>	<b>93%</b>	<b>99%</b>

25.0	25.0	5.00	5.00	25.0	25.0	100	25.0	NS
1.03	3.68	1.34	0.063 U	0.0141 BJ	0.0277 J	0.0923 J	0.152	N/A
21.4	20.8	6.33	6.28	21.7	20.6	105	19.7	NS
20.4	17.1	4.99	6.28	21.7	20.6	105	19.5	N/A
<b>82%</b>	<b>68%<sub>w</sub></b>	<b>100%</b>	<b>126%</b>	<b>87%</b>	<b>82%</b>	<b>105%</b>	<b>78%</b>	<b>N/A</b>

[illegible]

NS	NS	NS	NS	NS	NS	25.0	NS	NS
N/A	N/A	N/A	N/A	N/A	N/A	0.518	N/A	N/A
NS	NS	NS	NS	NS	NS	23.2	NS	NS
N/A	N/A	N/A	N/A	N/A	N/A	22.7	N/A	N/A
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>91%</b>	<b>N/A</b>	<b>N/A</b>

20.0	20.0	NS	NS	20.0	25.0	NS	20.0	0.0292
0.948	15.6	N/A	N/A	0.013 U	0.0864	N/A	0.318	0.00503 J
24.4	36.4	NS	NS	21.0	22.6	NS	20.5	0.0337
23.5	20.8	N/A	N/A	21.0	22.5	N/A	20.2	0.0287
<b>118%</b>	<b>104%</b>	<b>N/A</b>	<b>N/A</b>	<b>105%</b>	<b>90%</b>	<b>N/A</b>	<b>101%</b>	<b>98%</b>

[illegible]

N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	108%
25.0	25.0	NS	5.00	25.0	25.0	25.0	25.0	NS
6.17	12.7	N/A	0.123 J	0.0219 BJ	0.0156 J	0.606	2.07	N/A
30.4	35.3	NS	6.07	21.4	23.8	23.1	23.9	NS
24.2	22.6	N/A	5.95	21.4	23.8	22.5	21.8	N/A
97%	90%	N/A	119%	86%	95%	90%	87%	N/A
NS	NS	5.00	NS	NS	NS	NS	NS	NS
N/A	N/A	2.60	N/A	N/A	N/A	N/A	N/A	N/A
NS	NS	7.46	NS	NS	NS	NS	NS	NS
N/A	N/A	4.86	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	97%	N/A	N/A	N/A	N/A	N/A	N/A
NS	NS	5.00	NS	NS	NS	25.0	NS	NS
N/A	N/A	2.60	N/A	N/A	N/A	0.655	N/A	N/A
NS	NS	7.46	NS	NS	NS	22.2	NS	NS
N/A	N/A	4.86	N/A	N/A	N/A	21.5	N/A	N/A
N/A	N/A	97%	N/A	N/A	N/A	86%	N/A	N/A
25.0	25.0	5.00	5.00	25.0	25.0	NS	25.0	NS
1.44	3.28	1.49	0.063 U	0.0495 BJ	0.0233 J	N/A	0.522	N/A
25.2	22.0	6.35	4.02	25.9	24.8	NS	24.1	NS
23.8	18.7	4.86	4.02	25.8	24.8	N/A	23.6	N/A
95%	75%	97%	80%	103%	99%	N/A	94%	N/A
NS	NS	NS	NS	NS	NS	NS	NS	0.0138
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00446 J
NS	NS	NS	NS	NS	NS	NS	NS	0.0183
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.0138
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100%
NS	NS	5.00	5.00	NS	NS	NS	NS	NS
N/A	N/A	1.25	0.063 U	N/A	N/A	N/A	N/A	N/A
NS	NS	6.20	5.78	NS	NS	NS	NS	NS
N/A	N/A	4.95	5.78	N/A	N/A	N/A	N/A	N/A



0.546 B NA	32.8 NA	3.45 NA	0.683 NA	0.0178 BJ NA	0.0510 NA	0.608 0.427 J	0.238 NA	0.00507 J NA
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>35% *</b>	<b>N/A</b>	<b>N/A</b>
3.40 3.42	19.9 20.7	3.00 NA	1.56 NA	0.0132 BJ 0.0149 BJ	0.0169 J 0.0169 J	0.829 NA	0.186 0.184	0.0126 NA
<b>1%</b>	<b>4%</b>	<b>N/A</b>	<b>N/A</b>	<b>12%</b>	<b>0%</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>
1.40 NA	23.3 NA	3.16 NA	1.43 NA	0.013 U NA	0.0194 J NA	0.908 NA	0.183 NA	0.0162 0.0167
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>3%</b>
2.41 2.41	7.52 13.4	1.47 1.47	0.063 U 0.0670 J	0.0374 BJ 0.0259 BJ	0.0287 J 0.0312 J	0.585 NA	0.724 0.714	0.00388 J NA
<b>0%</b>	<b>56% *</b>	<b>0%</b>	<b>N/A</b>	<b>36% *</b>	<b>N/A</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>
6.17 NA	12.7 NA	2.86 NA	0.123 J NA	0.0219 BJ NA	0.0156 J NA	0.659 0.552	2.07 NA	0.0172 NA
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>18%</b>	<b>N/A</b>	<b>N/A</b>
3.47 NA	7.19 NA	2.66 NA	0.0714 J NA	0.0267 BJ NA	0.014 U NA	0.767 NA	1.11 NA	0.00857 J 0.00981 J
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>13%</b>
1.40 1.39	1.80 1.76	1.18 NA	0.063 U NA	0.0269 BJ 0.0490 BJ	0.0346 J 0.0308 J	0.679 0.630	0.165 0.158	0.00340 J NA
<b>1%</b>	<b>2%</b>	<b>N/A</b>	<b>N/A</b>	<b>58% *</b>	<b>12%</b>	<b>7%</b>	<b>4%</b>	<b>N/A</b>
1.26	13.3	1.32	0.063 U	0.0279 BJ	0.0615	0.992	0.214	0.00433 J

NA	NA	NA	NA	NA	NA	NA	NA	0.00424 J
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>2%</b>
1.36	4.05	1.84	0.063 U	0.0557 BJ	0.0176 J	0.718	0.653	0.00381 J
NA	NA	1.86	0.063 U	NA	NA	NA	NA	NA
<b>N/A</b>	<b>N/A</b>	<b>1%</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>
1.09	2.24	1.18	0.063 U	0.013 U	0.0257 J	0.268 J	0.126	0.00572 J
1.07	2.13	1.16	0.063 U	0.013 U	0.014 U	NA	0.121	NA
<b>2%</b>	<b>5%</b>	<b>2%</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>4%</b>	<b>N/A</b>
0.988	2.56	1.19	0.063 U	0.013 U	0.0239 J	0.0719 J	0.375	0.00443 J
NA	NA	NA	NA	NA	NA	NA	NA	0.00404 J
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>9%</b>
0.624 B	7.37	1.42	0.063 U	0.013 U	0.0270 J	0.152 J	0.670	0.00309 J
NA	NA	NA	NA	NA	NA	0.0757 j	NA	NA
<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>67% *</b>	<b>N/A</b>	<b>N/A</b>



**BATTELLE MARINE SCIENCES LABORATORY**  
**1529 W. Sequim Bay Road**  
**Sequim, WA 98382**  
**(360) 683-4151**

**SPAWAR**  
**CONCENTRATIONS OF METALS IN SEDIMENT SAMPLES**  
**Samples Received: 12/9/02**  
(concentrations in  $\mu\text{g/g}$  dry weight - not blank corrected)

**(cf#1781)**

MSL Code	Sponsor Rep I.D.	Al ICP/MS	Fe ICP/MS	Cr ICP/MS	Mn ICP/MS	Ni ICP/MS	Cu ICP/MS	Zn ICP/MS	As ICP/MS	Se FIAS	Ag GFAA	Cd ICP-MS	Sb ICP-MS
SAMPLE RESULTS													
1939*11	BPC-ltsd-Pb210 (0-2)	16800	16400	154	301	33.9	158	459	10.5	0.291	0.343	0.337	8.90
1939*12	BPC-ltsd-Pb210 (2-4)	14500	15800	71.4	262	32.2	164	267	12.0	0.218	0.350	0.248	7.68
1939*13	BPC-ltsd-Pb210 (4-6)	16100	15400	63.8	253	33.2	172	252	7.63	0.257	0.343	0.235	8.01
1939*14	BPC-ltsd-Pb210 (6-8)	16600	15600	64.7	256	34.4	187	464	15.7	0.211	0.372	0.720	7.27
1939*15	BPC-ltsd-Pb210 (8-10)	17800	17400	66.6	270	34.5	225	322	11.2	0.154	0.349	0.301	8.67
1939*16	BPC-ltsd-Pb210 (10-15)	11800	41600	69.5	328	38.9	130	493	14.4	0.157	0.357	0.652	11.9
1939*17	BPC-ltsd-Pb210 (20-25)	21400	22500	92.5	342	49.6	69.2	582	15.5	0.141	0.288	1.72	12.7
1939*18	BPC-ltsd-Pb210 (30-35)	29900	29800	113	500	62.1	34.0	91.3	15.7	0.139 U	0.028 U	0.200	2.14
1939*19	BPC-ltsd-Pb210 (40-45)	26300	27500	104	478	55.1	25.3	72.1	16.8	0.139 U	0.028 U	0.0205	1.31
1939*20	BPC-ltsd-Pb210 (50-55)	17500	20800	78.5	363	47.9	24.6	107	12.5	0.139 U	0.028 U	0.179	2.05
1939*31	SLC-ltsd-Pb210 (0-2)	53700	51600	179	779	94.9	371	478	21.6	0.506	1.10	0.480	14.1
1939*32	SLC-ltsd-Pb210 (2-4)	60300	53800	172	738	95.2	270	488	14.5	0.504	0.939	1.01	35.3
1939*33	SLC-ltsd-Pb210 (4-6)	53700	55600	383	778	108	588	1140	21.6	0.525	0.897	1.52	28.5
1939*34	SLC-ltsd-Pb210 (6-8)	61900	57300	199	864	106	183	335	17.5	0.686	0.760	1.28	12.2
1939*35	SLC-ltsd-Pb210 (10-15)	65100	57800	203	879	108	142	300	13.2	0.591	0.658	1.13	8.91
1939*36	SLC-ltsd-Pb210 (20-25)	65800	57700	210	851	109	152	313	14.2	0.586	0.826	0.847	9.26
1939*37	SLC-ltsd-Pb210 (30-35)	56700	62100	188	737	113	209	734	12.1	0.529	0.992	1.65	30.5
1939*38	SLC-ltsd-Pb210 (40-45)	67800	62000	220	748	126	149	504	11.0	0.360	0.537	2.10	11.7
1939*39	SLC-ltsd-Pb210 (50-55)	80600	65400	221	706	142	134	272	16.1	0.206	0.319	0.785	7.94
1939*40	SLC-ltsd-Pb210 (55-60)	84800	70200	233	746	154	131	266	14.8	0.204	0.299	1.03	8.82
PROCEDURAL BLANK		100	12.1	0.838	0.915	0.338	0.0485	2.01	2.01	0.139 U	0.028 U	0.0541	0.641
Instrument Detection Limit		0.524	0.564 ~	0.070 ~	0.056 ~	0.012	0.022	0.017	0.088	0.139	0.028	0.006	0.007
Client Reporting Limit		N/S	N/S	2.00	N/S	5.00	0.55	1.00	0.50	0.100	0.100	0.200	0.500
Method Detection Limit		1.43	NA	0.070	0.056	0.049	0.130	1.02	0.188	NA	0.026	0.059	NA
STANDARD REFERENCE MATERIAL													
PACS-2		70300	36800	84.3	432	38.2	283	360	25.8	1.08	1.06	2.24	22.4
PACS-2	certified value	66200	40900	90.7	440	39.5	310	364	26.2	0.92	1.22	2.11	19.8
PACS-2	range	±3200	±0.06	±4.6	±19	±2.3	±12	±23	±1.5	±0.22	±0.14	±0.15	±2.5
	% difference	6%	10%	7%	2%	3%	9%	1%	2%	18%	13%	6%	13%
ICV, CCV Results													

## BLANK SPIKE RESULTS

Amount Spiked	1000	1000	100	1000	50.0	100	1000	50.0	10.0	10.0	10.0	50.0
Blank (mean)	100	12.1	0.838	0.915	0.338	0.0485	2.01	2.01	0.139 U	0.028 U	0.0541	0.641
Blank + Spike	1110	1040	104	998	49.2	104	950	51.8	11.0	10.7	9.91	55.7
Amount Recovered	1010	1028	103	997	48.9	104	948	49.8	11.0	10.7	9.86	55.1
<b>Percent Recovery</b>	<b>101%</b>	<b>103%</b>	<b>103%</b>	<b>100%</b>	<b>98%</b>	<b>104%</b>	<b>95%</b>	<b>100%</b>	<b>110%</b>	<b>107%</b>	<b>99%</b>	<b>110%</b>

#### MATRIX SPIKE RESULTS

Amount Spiked	926	962	98.0	962	49.0	98.0	962	49.0	10.0	10.0	49.0	49.0
1939*18	29900	29800	113	500	62.1	34.0	91.3	15.7	0.139 U	0.028 U	0.200	2.14
1939*18 + Spike	30500	30800	215	1440	112	122	964	66.6	9.91	9.82	50.8	55.1
Amount Recovered	600	1000	102	940	49.9	88.0	873	50.9	9.91	9.82	50.6	53.0
<b>Percent Recovery</b>	<b>65%</b>	<b>104%</b>	<b>104%</b>	<b>98%</b>	<b>102%</b>	<b>90%</b>	<b>91%</b>	<b>104%</b>	<b>99%</b>	<b>98%</b>	<b>103%</b>	<b>108%</b>

#### REPLICATE RESULTS

1939*11	1	BPC-ltsd-Pb210 (0-2)	16800	16400	154	301	33.9	158	459	10.5	0.291	0.343	0.337	8.90
1939*11	2	BPC-ltsd-Pb210 (0-2)	15700	16400	64.0	300	32.9	159	231	14.9	0.163	0.331	0.006 U	8.87
										<b>0</b>				
		<b>RPD</b>	<b>7%</b>	<b>0%</b>	<b>83% *</b>	<b>0%</b>	<b>3%</b>	<b>1%</b>	<b>66% *</b>	<b>35% *</b>	<b>56% *</b>	<b>4%</b>	<b>N/A</b>	<b>0%</b>

U = not detected at or above detection limit.

J = result less than the instrument detection limit, but more than the MDL.

~ = IDL was 0, used MDL instead.

\* = duplicate is out of control.

e = SRM recovery is out of control.

w = spike recovery is out of control due to inappropriate spiking level.

NC = not certified.

NA = not analyzed.

N/A = not applicable.

N/S = not supplied.

NR = not reported.

NOTE: The lowest of the IDL, MDL or client reporting limit was used in all cases in an effort to provide the most informative and best quality data.



Project Name  
Project Number

SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample	Standard Reference Material	BPC-ITSD-PB 210 (0-2)	BPC-ITSD-PB 210 (2-4)	BPC-ITSD-PB 210 (4-6)	BPC-ITSD-PB 210 (6-8)
Battelle Sample ID	AB769PB	AB770LCS	AB771SRM	U2034	U2035	U2036	U2037
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002
Data File	A1058.D	A1059.D	A1060.D	A1061.D	A1062.D	A1064.D	A1065.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	13	1	1.05	4.99	11.53	7.45	9.07
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1	1
Min Reporting Limit	1.282307692	16.67	15.87619048	3.34	1.45	2.24	1.84
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene	0.47 J	813.78	855.09	15.24	14.28	21.19	38.49
C1-Naphthalenes	0.16 J	44.83 U	465.78	8.90	8.41	14.18	20.97
C2-Naphthalenes	3.45 U	44.83 U	925.52	17.74	13.30	17.42	118.71
C3-Naphthalenes	3.45 U	44.83 U	1235.50	106.10	41.11	24.90	551.75
C4-Naphthalenes	3.45 U	44.83 U	1008.39	163.44	49.20	35.68	448.57
2-Methylnaphthalene	0.11 J	788.52	460.30	9.94	9.77	15.73	27.88
1-Methylnaphthalene	0.06 J	777.17	283.79	3.94	3.49	6.89	5.11
2,6-Dimethylnaphthalene	0.08 U	806.04	478.44	10.95	9.39	12.10	39.67
2,3,5-Trimethylnaphthalene	0.06 U	777.44	280.61	18.13	5.01	5.53	139.05
Biphenyl	0.04 U	805.53	130.61	4.66	3.84	6.66	7.53
Acenaphthylene	0.06 U	786.16	144.25	105.08	43.20	55.61	105.28
Acenaphthene	0.04 U	809.30	266.56	34.20	20.19	34.40	296.52
Fluorene	0.05 U	818.31	339.16	138.76	111.65	121.21	1132.40
C1-Fluorenes	0.05 U	0.68 U	431.98	104.95	54.66	53.26	798.49
C2-Fluorenes	0.05 U	0.68 U	781.97	312.03	92.58	96.99	851.97
C3-Fluorenes	0.05 U	0.68 U	1007.34	406.88	122.59	142.22	892.63
Phenanthrene	0.07 U	814.13	3880.09	1009.49	780.35	1532.79	3813.33 D
Anthracene	0.06 U	800.94	729.42	4020.98 D	5214.60 D	1942.10	29715.94 D
C1-Phenanthrenes/Anthracenes	0.07 U	0.92 U	4065.83	2404.86	936.72	1176.97	6984.84
C2-Phenanthrenes/Anthracenes	0.07 U	0.92 U	4162.69	3722.76	977.41	1256.39	6092.69
C3-Phenanthrenes/Anthracenes	0.07 U	0.92 U	2590.38	2396.76	662.13	868.42	2998.67
C4-Phenanthrenes/Anthracenes	0.07 U	0.92 U	803.27	749.81	379.07	361.37	884.70
1-Methylphenanthrene	0.06 U	813.18	956.22	445.91	137.20	219.70	1494.08
Dibenzothiophene	0.05 U	0.71 U	501.53	77.03	24.96	66.36	597.25
C1-Dibenzothiophenes	0.05 U	0.71 U	1058.12	250.15	53.25	76.52	811.69
C2-Dibenzothiophenes	0.05 U	0.71 U	1773.91	847.21	130.88	199.31	1285.72
C3-Dibenzothiophenes	0.05 U	0.71 U	1449.18	1111.03	246.14	245.38	646.51
Fluoranthene	0.10 J	848.49	6949.10	31139.36 D	10759.54 D	11064.18 D	55446.22 D
Pyrene	0.16 JB	838.05	7358.36	31284.68 D	10095.11 D	10117.37 D	64233.28 D
C1-Fluoranthenes/Pyrenes	0.06 U	0.75 U	4994.86	17347.67	9004.15	9884.48	28256.30
C2-Fluoranthenes/Pyrenes	0.06 U	0.75 U	2989.93	5379.28	3085.06	4103.92	6994.93
C3-Fluoranthenes/Pyrenes	0.06 U	0.75 U	1313.41	2222.96	1725.59	1806.61	2939.63
Benzo(a)anthracene	0.08 J	771.57	3454.85	10562.77 D	5817.44 D	5137.49 D	19244.09 D
Chrysene	0.20 JB	837.42	4314.59	18082.57 D	10760.03 D	10946.53 D	23646.92 D
C1-Chrysenes	0.03 U	0.39 U	2618.06	5038.03	3872.69	4077.59	6808.67
C2-Chrysenes	0.03 U	0.39 U	1508.90	2032.88	1874.88	1900.33	2651.80
C3-Chrysenes	0.03 U	0.39 U	697.71	829.10	837.11	794.30	1141.32
C4-Chrysenes	0.03 U	0.39 U	256.29	285.17	319.25	315.49	369.79
Benzo(b)fluoranthene	0.31 JB	953.42	2984.10	10930.98 D	11189.08 D	11849.89 D	17976.84 D
Benzo(k)fluoranthene	0.46 JB	831.95	2722.21	12173.71 D	10092.80 D	11060.15 D	18060.28 D
Benzo(e)pyrene	0.31 JB	787.66	2574.99	8621.10 D	7817.81 D	8144.72 D	12269.16 D
Benzo(a)pyrene	0.31 JB	749.47	2789.97	7030.53 D	8950.04 D	8739.38 D	14082.12 D
Perylene	0.03 U	708.07	709.17	2249.35 D	2530.92 D	2394.13 D	3900.23 D
Indeno(1,2,3-c,d)pyrene	0.13 JB	699.07	2214.44	4148.06 D	4094.98 D	4062.15 D	5615.42 D
Dibenz(a,h)anthracene	0.04 U	768.34	539.60	1050.58 D	934.01 D	952.36 D	1317.43 D
Benzo(g,h,i)perylene	0.16 JB	634.26	1884.12	3145.05 D	2922.06 D	3048.08 D	4317.55 D



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
 Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample	Standard Reference Material	BPC-ITSD-PB 210 (0-2)	BPC-ITSD-PB 210 (2-4)	BPC-ITSD-PB 210 (4-6)	BPC-ITSD-PB 210 (6-8)
Battelle Sample ID	AB769PB	AB770LCS	AB771SRM	U2034	U2035	U2036	U2037
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002
Data File	A1058.D	A1059.D	A1060.D	A1061.D	A1062.D	A1064.D	A1065.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03	01/16/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	13	1	1.05	4.99	11.53	7.45	9.07
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1	1
Min Reporting Limit	1.282307692	16.67	15.87619048	3.34	1.45	2.24	1.84
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene-d8	48	80	66	70	72	67	73
Phenanthrene-d10	44	74	74	80	80	78	83
Chrysene-d12	48	80	78	100	97	100	98

U = Analyte not detected, the sample specific Method Detection Limit reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.

D = Result from dilution.

B = Analyte concentration found in the sample at a concentration <3x the level found in the procedure blank).



Project Name SPAW  
Project Number G6001

Client Sample ID	BPC-ITSD-PB 210 (8-10)	BPC-ITSD-PB 210 (10-15)	BPC-ITSD-PB 210 (20-25)	BPC-ITSD-PB 210 (30-35)
Battelle Sample ID	U2038	U2039	U2040	U2041
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1066.D	A1067.D	A1068.D	A1070.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/16/03	01/16/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	11.51	17.79	19.02	20.14
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	1.45	0.94	0.88	0.83
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene	21.73	11.24	37.49	1.39 B
C1-Naphthalenes	11.03	6.33	5.29	0.56 J
C2-Naphthalenes	17.37	6.48	8.07	0.73 J
C3-Naphthalenes	23.53	6.71	9.32	0.59 J
C4-Naphthalenes	24.68	11.49	30.44	2.23 U
2-Methylnaphthalene	10.87	6.98	5.76	0.53 J
1-Methylnaphthalene	6.74	3.02	2.40	0.22 J
2,6-Dimethylnaphthalene	7.20	3.83	3.79	0.36 J
2,3,5-Trimethylnaphthalene	7.12	1.32	1.85	0.14 J
Biphenyl	3.35	2.77	2.36	0.25 J
Acenaphthylene	56.34	20.05	5.47	0.67 J
Acenaphthene	54.75	13.64	5.20	0.32 J
Fluorene	61.25	20.20	8.10	0.52 J
C1-Fluorenes	41.30	9.05	7.32	0.44 J
C2-Fluorenes	60.01	16.27	22.85	0.94
C3-Fluorenes	80.20	28.42	70.66	2.46
Phenanthrene	771.94	131.16	72.80	4.36
Anthracene	550.13	120.47	22.09	2.57
C1-Phenanthrenes/Anthracenes	635.66	138.19	56.01	4.14
C2-Phenanthrenes/Anthracenes	552.10	152.93	89.71	6.39
C3-Phenanthrenes/Anthracenes	410.45	124.88	91.99	4.65
C4-Phenanthrenes/Anthracenes	266.90	87.99	78.19	2.63
1-Methylphenanthrene	147.44	24.30	12.86	1.10
Dibenzothiophene	30.54	6.84	5.52	0.41 J
C1-Dibenzothiophenes	46.15	8.11	9.61	0.96
C2-Dibenzothiophenes	77.93	23.23	19.67	2.11
C3-Dibenzothiophenes	158.43	50.17	51.26	3.28
Fluoranthene	3732.08 D	1307.30 D	236.15	44.66
Pyrene	5954.19 D	1633.26 D	279.92	50.41
C1-Fluoranthenes/Pyrenes	7029.11	1908.75	443.58	36.54
C2-Fluoranthenes/Pyrenes	2967.46	1059.33	617.70	28.94
C3-Fluoranthenes/Pyrenes	1781.23	666.21	626.43	23.41
Benzo(a)anthracene	3388.31 D	915.77	165.17	22.55
Chrysene	6596.31 D	2001.85 D	288.80	46.76
C1-Chrysenes	4287.07	1060.94	212.02	17.47
C2-Chrysenes	2381.13	755.67	444.55	17.47
C3-Chrysenes	1013.00	421.08	504.34	17.70
C4-Chrysenes	381.49	175.15	243.23	9.14
Benzo(b)fluoranthene	11325.46 D	4814.08 D	1111.56	105.37
Benzo(k)fluoranthene	11071.54 D	4604.58 D	801.37	85.44
Benzo(e)pyrene	8090.27 D	3131.24 D	506.67	47.14
Benzo(a)pyrene	9287.15 D	4086.38 D	813.95	78.16
Perylene	2133.82 D	713.21 D	164.76	12.25
Indeno(1,2,3-c,d)pyrene	5313.17 D	1927.18 D	545.82	48.35
Dibenz(a,h)anthracene	1272.10 D	466.77 D	142.82	11.59
Benzo(g,h,i)perylene	4318.88 D	1497.88 D	414.71	35.17



Project Name SPAW  
Project Number G6001

Client Sample ID	BPC-ITSD-PB 210 (8-10)	BPC-ITSD-PB 210 (10-15)	BPC-ITSD-PB 210 (20-25)	BPC-ITSD-PB 210 (30-35)
Battelle Sample ID	U2038	U2039	U2040	U2041
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1066.D	A1067.D	A1068.D	A1070.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/16/03	01/16/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	11.51	17.79	19.02	20.14
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	1.45	0.94	0.88	0.83
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene-d8	69	61	60	59
Phenanthrene-d10	82	70	76	70
Chrysene-d12	113	84	88	78

U = Analyte not detected, the sample  
J = Analyte detected below the samp  
NA = Not applicable.  
N = QC value outside the accuracy o  
D = Result from dilution.  
B = Analyte concentration found in th



Project Name SPAW  
Project Number G6001

Client Sample ID	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (50-55)	SLC-ITSD-PB 210 (0-2)	SLC-ITSD-PB 210 (2-4)
Battelle Sample ID	U2042	U2042MS	U2042MSD	U2043	U2044	U2045
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002
Data File	A1071.D	A1072.D	A1073.D	A1074.D	A1076.D	A1077.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	20.46	10.83	10.7	21.2	5.26	8.91
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	0.81	1.54	1.56	0.79	3.17	1.87
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene	1.85	50.93	55.63	1.51	10.03	17.93
C1-Naphthalenes	0.56 J	4.14 U	4.19 U	0.73 J	6.37	11.59
C2-Naphthalenes	0.63 J	4.14 U	4.19 U	1.37	11.05	42.93
C3-Naphthalenes	0.46 J	4.14 U	4.19 U	1.60	23.61	215.48
C4-Naphthalenes	2.19 U	4.14 U	4.19 U	4.18	95.89	830.22
2-Methylnaphthalene	0.61 J	53.07	57.31	0.71 J	6.68	12.25
1-Methylnaphthalene	0.28 J	52.96	57.65	0.34 J	3.23	5.45
2,6-Dimethylnaphthalene	0.32 J	57.21	63.67	0.53 J	5.37	19.99
2,3,5-Trimethylnaphthalene	0.15 J	59.61	67.31	0.05 J	4.06	52.71
Biphenyl	0.24 J	56.52	63.25	0.28 J	2.61 J	4.35
Acenaphthylene	0.66 J	56.14	62.13	1.49	13.50	11.74
Acenaphthene	0.60 J	59.01	64.88	0.32 J	12.70	39.58
Fluorene	0.60 J	61.60	71.34	0.46 J	23.05	26.69
C1-Fluorenes	0.29 J	0.06 U	0.06 U	0.52 J	30.19	46.18
C2-Fluorenes	0.91	0.06 U	0.06 U	2.75	72.88	477.34
C3-Fluorenes	2.21	0.06 U	0.06 U	0.03 U	195.71	1114.95
Phenanthrene	4.90	66.78	78.30	4.59	275.20	95.82
Anthracene	2.37	64.24	74.42	2.45	151.51	162.19
C1-Phenanthrenes/Anthracenes	3.13	0.08 U	0.09 U	5.99	265.39	253.11
C2-Phenanthrenes/Anthracenes	5.23	0.08 U	0.09 U	9.48	213.24	979.13
C3-Phenanthrenes/Anthracenes	3.33	0.08 U	0.09 U	7.09	275.61	1787.85
C4-Phenanthrenes/Anthracenes	1.39	0.08 U	0.09 U	7.00	264.89	1144.67
1-Methylphenanthrene	0.73 J	68.35	78.75	1.26	50.82	24.64
Dibenzothiophene	0.34 J	0.96 J	1.30 J	0.52 J	15.50	18.75
C1-Dibenzothiophenes	0.57 J	0.07 U	0.07 U	1.59	32.49	87.26
C2-Dibenzothiophenes	0.90	0.07 U	0.07 U	2.13	129.38	1272.15
C3-Dibenzothiophenes	1.45	0.07 U	0.07 U	3.31	580.83	3651.07
Fluoranthene	15.78	82.33	90.87	126.18	931.38	1441.39
Pyrene	19.93	85.21	94.76	119.17	1764.21	4786.42 D
C1-Fluoranthenes/Pyrenes	24.83	0.07 U	0.07 U	53.50	1522.50	2956.50
C2-Fluoranthenes/Pyrenes	17.02	0.07 U	0.07 U	58.81	919.40	2049.05
C3-Fluoranthenes/Pyrenes	11.66	0.07 U	0.07 U	47.22	817.96	1866.07
Benzo(a)anthracene	12.88	73.43	84.62	34.39	705.94	1098.63
Chrysene	32.54	86.15	98.18	87.72	1284.82	1613.41
C1-Chrysenes	12.38	0.04 U	0.04 U	20.81	593.83	1245.13
C2-Chrysenes	11.13	0.04 U	0.04 U	8.77	595.43	1370.50
C3-Chrysenes	8.38	0.04 U	0.04 U	26.66	518.48	1154.57
C4-Chrysenes	0.02 U	0.04 U	0.04 U	19.11	261.52	536.36
Benzo(b)fluoranthene	74.68	128.46	154.69	192.30	2103.26	2488.17 D
Benzo(k)fluoranthene	64.07	123.30	148.82	162.47	1666.11	1861.06
Benzo(e)pyrene	22.44	82.31	97.83	78.82	1341.70	1603.81
Benzo(a)pyrene	55.90	112.08	137.50	119.80	1350.39	1895.13
Perylene	7.93	69.43	81.15	14.68	423.14	602.72
Indeno(1,2,3-c,d)pyrene	31.98	89.90	107.11	88.47	933.15	1020.39
Dibenz(a,h)anthracene	7.95	76.03	88.70	20.90	238.54	274.44
Benzo(g,h,i)perylene	22.62	76.94	93.10	64.04	678.93	759.17



Project Name SPAW  
Project Number G6001

Client Sample ID	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (40-45)	BPC-ITSD-PB 210 (50-55)	SLC-ITSD-PB 210 (0-2)	SLC-ITSD-PB 210 (2-4)
Battelle Sample ID	U2042	U2042MS	U2042MSD	U2043	U2044	U2045
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002	03-0002	03-0002
Data File	A1071.D	A1072.D	A1073.D	A1074.D	A1076.D	A1077.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	20.46	10.83	10.7	21.2	5.26	8.91
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	0.81	1.54	1.56	0.79	3.17	1.87
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene-d8	55	61	66	69	65	71
Phenanthrene-d10	64	64	73	77	78	81
Chrysene-d12	72	72	81	85	86	90

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Project Name SPAW  
Project Number G6001

Client Sample ID	SLC-ITSD-PB 210 (4-6)	SLC-ITSD-PB 210 (6-8)	SLC-ITSD-PB 210 (10-15)	SLC-ITSD-PB 210 (20-25)
Battelle Sample ID	U2046	U2047	U2048	U2049
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1078.D	A1079.D	A1080.D	A1082.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	7.18	6.79	12.32	11.4
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	2.32	2.46	1.35	1.46
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene	34.47	9.21	8.77	11.26
C1-Naphthalenes	18.42	11.11	23.29	29.22
C2-Naphthalenes	56.55	84.44	113.81	195.22
C3-Naphthalenes	225.24	193.01	140.29	488.21
C4-Naphthalenes	831.99	717.16	579.58	1844.76
2-Methylnaphthalene	19.68	6.82	8.06	7.06
1-Methylnaphthalene	8.79	10.40	27.58	38.59
2,6-Dimethylnaphthalene	21.55	14.45	9.64	13.38
2,3,5-Trimethylnaphthalene	52.47	39.65	27.87	177.56
Biphenyl	5.71	2.46	2.50	3.57
Acenaphthylene	31.37	26.76	31.17	38.76
Acenaphthene	37.88	138.97	28.93	59.51
Fluorene	23.45	34.10	9.77	7.95
C1-Fluorenes	66.71	67.27	46.32	166.59
C2-Fluorenes	597.84	627.57	568.74	1307.84
C3-Fluorenes	1345.24	1585.86	1442.57	2069.25
Phenanthrene	150.52	202.25	34.38	53.97
Anthracene	217.47	78.95	38.77	60.34
C1-Phenanthrenes/Anthracenes	421.62	303.89	218.12	414.14
C2-Phenanthrenes/Anthracenes	1438.92	1898.69	1911.67	3213.98
C3-Phenanthrenes/Anthracenes	2311.76	3179.34	3426.30	4297.19
C4-Phenanthrenes/Anthracenes	1712.95	1932.16	1810.38	2316.47
1-Methylphenanthrene	86.19	27.35	9.48	36.19
Dibenzothiophene	22.36	26.17	13.30	18.29
C1-Dibenzothiophenes	118.65	98.63	91.86	200.66
C2-Dibenzothiophenes	1374.85	1383.14	1228.89	2379.42
C3-Dibenzothiophenes	3798.81	3881.96	3786.04	4974.25
Fluoranthene	1625.30	867.65	520.85	1262.16
Pyrene	5095.17 D	2156.65	1250.79	1742.03
C1-Fluoranthenes/Pyrenes	3687.04	2349.87	1956.56	2572.29
C2-Fluoranthenes/Pyrenes	2478.98	2380.46	2209.88	2615.49
C3-Fluoranthenes/Pyrenes	2165.21	2321.05	2223.99	2585.98
Benzo(a)anthracene	1565.13	600.11	432.65	833.41
Chrysene	2443.34 D	734.18	480.83	855.85
C1-Chrysenes	1678.95	1211.56	1046.39	1383.99
C2-Chrysenes	1625.77	1678.89	1689.85	2000.80
C3-Chrysenes	1363.67	1456.71	1505.95	1846.81
C4-Chrysenes	578.35	724.12	651.50	842.55
Benzo(b)fluoranthene	2246.90	976.10	389.82	605.11
Benzo(k)fluoranthene	1642.11	712.35	285.34	440.00
Benzo(e)pyrene	1657.83	752.71	384.08	555.32
Benzo(a)pyrene	1758.88	738.50	314.48	501.44
Perylene	572.76	331.93	236.62	313.79
Indeno(1,2,3-c,d)pyrene	1104.28	420.46	190.78	282.01
Dibenz(a,h)anthracene	297.36	119.27	62.07	90.55
Benzo(g,h,i)perylene	860.23	325.65	179.83	252.41



Project Name SPAW.  
Project Number G6001

Client Sample ID	SLC-ITSD-PB 210 (4-6)	SLC-ITSD-PB 210 (6-8)	SLC-ITSD-PB 210 (10-15)	SLC-ITSD-PB 210 (20-25)
Battelle Sample ID	U2046	U2047	U2048	U2049
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1078.D	A1079.D	A1080.D	A1082.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	7.18	6.79	12.32	11.4
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	2.32	2.46	1.35	1.46
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene-d8	67	63	62	70
Phenanthrene-d10	79	76	71	80
Chrysene-d12	90	85	82	89

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D = Result from dilution.  
B = Analyte concentration found in th



Project Name SPAW  
Project Number G6001

Client Sample ID	SLC-ITSD-PB 210 (30-35)	SLC-ITSD-PB 210 (40-45)	SLC-ITSD-PB 210 (50-55)	SLC-ITSD-PB 210 (55-60)
Battelle Sample ID	U2050	U2051	U2052	U2053
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1083.D	A1084.D	A1085.D	A1086.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	13.71	16.44	19.32	21.11
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	1.22	1.01	0.86	0.79
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene	18.79	16.06	29.19	13.12
C1-Naphthalenes	35.35	21.35	110.70	32.66
C2-Naphthalenes	565.79	718.42	5703.53	1776.92
C3-Naphthalenes	4801.03	4859.53	18131.62	8117.50
C4-Naphthalenes	6480.05	4842.70	14257.62	6775.20
2-Methylnaphthalene	8.41	6.46	7.61	4.50
1-Methylnaphthalene	48.89	24.50	175.35	41.29
2,6-Dimethylnaphthalene	61.65	166.21	2145.43 D	555.25
2,3,5-Trimethylnaphthalene	1314.69 D	1392.42 D	4907.11 D	2165.59 D
Biphenyl	4.62	5.00	8.33	3.27
Acenaphthylene	42.68	24.28	108.37	38.41
Acenaphthene	403.56	266.00	496.23	240.37
Fluorene	21.84	37.42	626.79	176.77
C1-Fluorenes	652.46	664.69	3029.86	1273.31
C2-Fluorenes	3245.09	2352.45	6328.66	3119.47
C3-Fluorenes	3568.87	2309.11	4935.88	2443.27
Phenanthrene	169.42	24.86	2039.42 D	369.03
Anthracene	487.90 D	221.85	441.75 D	216.43
C1-Phenanthrenes/Anthracenes	1680.13	1304.72	7826.13	2698.95
C2-Phenanthrenes/Anthracenes	6520.32	4690.58	12758.96	6150.72
C3-Phenanthrenes/Anthracenes	6511.91	4749.85	9616.47	5107.80
C4-Phenanthrenes/Anthracenes	2969.84	2092.06	3646.51	1858.65
1-Methylphenanthrene	336.45	304.35	2322.20 D	753.72
Dibenzothiophene	65.95	37.36	421.27	79.97
C1-Dibenzothiophenes	968.72	885.99	3974.75	1832.68
C2-Dibenzothiophenes	6213.01	3920.62	8025.02	4170.76
C3-Dibenzothiophenes	9799.20	5413.53	7248.64	4081.20
Fluoranthene	3350.69 D	1230.58	1261.80 D	762.25
Pyrene	3903.11 D	2100.57 D	2301.44 D	1362.54 D
C1-Fluoranthenes/Pyrenes	3548.60	2488.41	3693.59	2065.31
C2-Fluoranthenes/Pyrenes	3659.75	2698.66	4124.65	2253.77
C3-Fluoranthenes/Pyrenes	3502.42	2639.66	3775.05	2092.28
Benzo(a)anthracene	1102.16	562.59	578.29	364.74
Chrysene	1268.05	658.15	1192.93 D	574.24
C1-Chrysenes	1828.66	1399.57	2146.63	1173.18
C2-Chrysenes	2743.84	2075.41	3227.73	1672.00
C3-Chrysenes	2452.92	1731.60	2537.51	1476.89
C4-Chrysenes	1031.05	774.72	1140.41	571.08
Benzo(b)fluoranthene	917.95	417.36	266.85	203.13
Benzo(k)fluoranthene	650.15	263.54	159.35	125.02
Benzo(e)pyrene	800.75	427.15	406.23	268.14
Benzo(a)pyrene	757.30	344.39	297.32	204.89
Perylene	347.34	227.35	322.69	182.31
Indeno(1,2,3-c,d)pyrene	421.43	187.60	122.72	101.61
Dibenz(a,h)anthracene	138.44	59.89	46.46	35.84
Benzo(g,h,i)perylene	380.99	188.49	156.30	114.36



Project Name SPAW.  
Project Number G6001

Client Sample ID	SLC-ITSD-PB 210 (30-35)	SLC-ITSD-PB 210 (40-45)	SLC-ITSD-PB 210 (50-55)	SLC-ITSD-PB 210 (55-60)
Battelle Sample ID	U2050	U2051	U2052	U2053
Battelle Batch ID	03-0002	03-0002	03-0002	03-0002
Data File	A1083.D	A1084.D	A1085.D	A1086.D
Extraction Date	01/03/03	01/03/03	01/03/03	01/03/03
Acquired Date	01/17/03	01/17/03	01/17/03	01/17/03
Matrix	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	13.71	16.44	19.32	21.11
Dilution Factor	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1
Min Reporting Limit	1.22	1.01	0.86	0.79
Amount Units	ng/g	ng/g	ng/g	ng/g
Naphthalene-d8	66	68	72	68
Phenanthrene-d10	76	66	69	67
Chrysene-d12	88	87	92	90

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Project Name SPAW  
Project Number G6001

Client Sample ID	SRM 1944
Battelle Sample ID	AB771SRM
Battelle Batch ID	03-0002
Data File	G1290A.D
Extraction Date	06/09/01
Acquired Date	02/06/03
Matrix	Sediment
Sample Size (g)	1.05 L
Dilution Factor	1.667
PIV (mL)	1.00 mL
Min Reporting Limit	15.88
Amount Units	ng/g
<hr/>	
Naphthalene	836.26
C1-Naphthalenes	42.70 U
C2-Naphthalenes	42.70 U
C3-Naphthalenes	42.70 U
C4-Naphthalenes	42.70 U
2-Methylnaphthalene	1.05 U
1-Methylnaphthalene	0.67 U
2,6-Dimethylnaphthalene	0.96 U
2,3,5-Trimethylnaphthalene	0.74 U
Biphenyl	0.49 U
Acenaphthylene	0.75 U
Acenaphthene	0.45 U
Fluorene	0.65 U
C1-Fluorenes	0.65 U
C2-Fluorenes	0.65 U
C3-Fluorenes	0.65 U
Phenanthrene	4088.15
Anthracene	751.82
C1-Phenanthrenes/Anthracenes	0.87 U
C2-Phenanthrenes/Anthracenes	0.87 U
C3-Phenanthrenes/Anthracenes	0.87 U
C4-Phenanthrenes/Anthracenes	0.87 U
1-Methylphenanthrene	0.80 U
Dibenzothiophene	0.68 U
C1-Dibenzothiophenes	0.68 U
C2-Dibenzothiophenes	0.68 U
C3-Dibenzothiophenes	0.68 U
Fluoranthene	6961.09
Pyrene	7409.66
C1-Fluoranthenes/Pyrenes	0.71 U
C2-Fluoranthenes/Pyrenes	0.71 U
C3-Fluoranthenes/Pyrenes	0.71 U
Benzo(a)anthracene	3697.77
Chrysene	4419.58
C1-Chrysenes	0.37 U
C2-Chrysenes	0.37 U
C3-Chrysenes	0.37 U
C4-Chrysenes	0.37 U
Benzo(b)fluoranthene	3178.38
Benzo(k)fluoranthene	3148.03
Benzo(e)pyrene	2713.72
Benzo(a)pyrene	2978.88
Perylene	772.41
Indeno(1,2,3-c,d)pyrene	2156.92
Dibenz(a,h)anthracene	705.63
Benzo(g,h,i)perylene	2036.79



Project Name SPAW  
Project Number G6001

Client Sample ID	SRM 1944
Battelle Sample ID	AB771SRM
Battelle Batch ID	03-0002
Data File	G1290A.D
Extraction Date	06/09/01
Acquired Date	02/06/03
Matrix	Sediment
Sample Size (g)	1.05 L
Dilution Factor	1.667
PIV (mL)	1.00 mL
Min Reporting Limit	15.88
Amount Units	ng/g
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Naphthalene-d8	63
Phenanthrene-d10	74
Chrysene-d12	79

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NA = Not applicable.  
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Project Name  
Project Number

SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample	SRM 1944	BPA-cpsd-PAH-U	BPA-cpsd-PAH-U	BPA-cpsd-PAH-U	BPB-cpsd-PAH-U	BPC-cpsd-PAH-U	BPA-cpsd-PAH-L
Battelle Sample ID	BB275PB	BB276LCS	BB277SRM	U5836	U5836MS-R1	U5836MSD	U5837	U5838	U5839
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1687.D	A1688.D	A1689.D	A1690.D	A1691.D	A1692.D	A1694.D	A1695.D	A1696.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	17	1	1.15	16.62	8.45	8.56	21	21.25	18.36
Dilution Factor	1.667	1.667	1.667	1.667	4.167	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1	1	1	1
Min Reporting Limit	0.98	16.67	14.50	1.00	4.93	1.95	0.79	0.78	0.91
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene	0.49 J	758.94	973.37	30.14	109.59	119.85	17.71	34.19	31.12
C1-Naphthalenes	0.25 J	44.83 U	38.98 U	20.42	13.26 U	5.24 U	21.48	16.31	20.90
C2-Naphthalenes	2.64 U	44.83 U	38.98 U	37.67	13.26 U	5.24 U	33.11	18.89	28.87
C3-Naphthalenes	2.64 U	44.83 U	38.98 U	59.89	13.26 U	5.24 U	38.24	25.39	35.63
C4-Naphthalenes	2.64 U	44.83 U	38.98 U	51.76	13.26 U	5.24 U	29.34	22.15	40.95
2-Methylnaphthalene	0.21 JB	755.70	523.96	21.19	110.04	117.14	21.54	17.07	21.37
1-Methylnaphthalene	0.16 JB	733.30	291.41	10.28	92.66	99.59	11.50	7.98	10.79
2,6-Dimethylnaphthalene	0.17 J	776.34	476.68	21.41	111.84	116.28	18.20	11.04	15.02
2,3,5-Trimethylnaphthalene	0.16 JB	769.77	278.66	12.09	106.51	109.18	6.37	3.65	6.04
Biphenyl	0.16 JB	789.29	140.68	9.73	98.24	102.83	10.24	7.07	21.31
Acenaphthylene	0.21 JB	800.61	192.66	121.14	227.32	233.63	101.49	79.28	165.12
Acenaphthene	0.16 JB	799.21	232.55	95.69	171.93	180.13	107.49	58.73	31.91
Fluorene	0.17 JB	813.30	297.84	149.22	259.31	237.46	181.96	96.96	78.12
C1-Fluorenes	0.04 U	0.68 U	0.59 U	84.47	0.20 U	0.08 U	65.58	37.69	45.84
C2-Fluorenes	0.04 U	0.68 U	0.59 U	130.46	0.20 U	0.08 U	83.32	47.90	95.42
C3-Fluorenes	0.04 U	0.68 U	0.59 U	178.12	0.20 U	0.08 U	81.11	62.59	143.64
Phenanthrene	0.25 JB	829.30	3767.04	2104.61 D	1355.06	1161.08	1466.64 D	583.36	662.01
Anthracene	0.20 JB	799.43	720.39	1337.77 D	2197.57	1603.09 D	2446.81 D	651.49	1076.63
C1-Phenanthrenes/Anthracenes	0.05 U	0.92 U	0.80 U	1161.21	0.27 U	0.11 U	806.12	411.65	615.66
C2-Phenanthrenes/Anthracenes	0.05 U	0.92 U	0.80 U	1104.50	0.27 U	0.11 U	668.06	374.65	684.36
C3-Phenanthrenes/Anthracenes	0.05 U	0.92 U	0.80 U	866.65	0.27 U	0.11 U	457.16	304.57	665.21
C4-Phenanthrenes/Anthracenes	0.05 U	0.92 U	0.80 U	787.72	0.27 U	0.11 U	318.96	287.99	735.03
1-Methylphenanthrene	0.17 JB	777.27	902.82	192.40	254.16	234.22	125.12	58.13	88.96
Dibenzothiophene	0.22 JB	10.02 J	483.84	87.96	58.86	52.12	66.42	27.79	28.25
C1-Dibenzothiophenes	0.04 U	0.71 U	0.62 U	87.51	0.21 U	0.08 U	53.27	24.35	40.52
C2-Dibenzothiophenes	0.04 U	0.71 U	0.62 U	203.09	0.21 U	0.08 U	97.21	47.18	102.63
C3-Dibenzothiophenes	0.04 U	0.71 U	0.62 U	466.61	0.21 U	0.08 U	167.43	119.14	351.90
Fluoranthene	0.21 JB	806.41	6523.12	7497.45 D	8978.97 D	6258.38 D	6215.77 D	2317.75 D	4062.97 D
Pyrene	0.23 JB	818.10	6835.56	9701.34 D	10987.52 D	9014.22 D	6327.03 D	2943.80 D	8528.98 D
C1-Fluoranthenes/Pyrenes	0.04 U	0.75 U	0.65 U	9025.45	0.22 U	0.09 U	6504.22	4126.85	9423.64
C2-Fluoranthenes/Pyrenes	0.04 U	0.75 U	0.65 U	4836.88	0.22 U	0.09 U	2769.76	1882.53	5487.05
C3-Fluoranthenes/Pyrenes	0.04 U	0.75 U	0.65 U	3108.87	0.22 U	0.09 U	1723.34	1354.60	4036.13
Benzo(a)anthracene	0.29 JB	737.25	3214.37	4545.23 D	4337.70	4977.67 D	3567.98 D	2316.92 D	3268.95 D
Chrysene	0.26 JB	795.21	4527.22	9966.69 D	11322.16 D	10130.88 D	6905.65 D	4593.56 D	7628.25 D
C1-Chrysenes	0.02 U	0.39 U	0.34 U	5001.31	0.12 U	0.05 U	3301.65	2341.27	4697.87
C2-Chrysenes	0.02 U	0.39 U	0.34 U	2898.44	0.12 U	0.05 U	1678.78	1316.82	3277.75
C3-Chrysenes	0.02 U	0.39 U	0.34 U	1503.17	0.12 U	0.05 U	766.68	680.98	1875.19
C4-Chrysenes	0.02 U	0.39 U	0.34 U	816.51	0.12 U	0.05 U	384.48	346.16	1004.26
Benzo(b)fluoranthene	0.29 JB	717.61	3037.16	15263.14 D	17089.78 D	16708.60 D	9857.03 D	7842.31 D	16850.46 D
Benzo(k)fluoranthene	0.21 JB	818.90	2971.39	12699.81 D	15590.45 D	14427.57 D	8550.63 D	6597.48 D	14540.51 D
Benzo(e)pyrene	0.29 JB	757.72	2652.39	9546.19 D	11011.48 D	11011.78 D	6362.78 D	4811.10 D	10795.53 D
Benzo(a)pyrene	0.25 JB	731.38	2942.76	11576.16 D	13259.20 D	13505.97 D	7668.36 D	6152.73 D	13491.99 D
Perylene	0.23 JB	703.74	752.18	2929.83 D	3362.42	3465.80 D	1923.10 D	1546.54 D	3098.82 D
Indeno(1,2,3-c,d)pyrene	0.22 JB	606.25	2152.84	5986.94 D	6665.67 D	6866.25 D	4305.56 D	3180.24 D	6690.22 D
Dibenz(a,h)anthracene	0.16 JB	676.72	547.07	1565.60 D	2885.07	1817.22 D	1078.03 D	789.57 D	1754.87 D
Benzo(g,h,i)perylene	0.31 JB	694.91	2428.63	4490.25 D	5364.79	4919.36 D	3165.19 D	2343.92 D	4854.89 D
Naphthalene-d8	75	76	68	67	70	76	71	72	67
Phenanthrene-d10	71	73	69	73	72	73	74	74	77
Chrysene-d12	67	72	75	108	77	95	106	97	121



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample	SRM 1944	BPA-cpsd-PAH-U	BPA-cpsd-PAH-U	BPA-cpsd-PAH-U	BPB-cpsd-PAH-U	BPC-cpsd-PAH-U	BPA-cpsd-PAH-L
Battelle Sample ID	BB275PB	BB276LCS	BB277SRM	U5836	U5836MS-R1	U5836MSD	U5837	U5838	U5839
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1687.D	A1688.D	A1689.D	A1690.D	A1691.D	A1692.D	A1694.D	A1695.D	A1696.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/26/03	02/27/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	17	1	1.15	16.62	8.45	8.56	21	21.25	18.36
Dilution Factor	1.667	1.667	1.667	1.667	4.167	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1	1	1	1
Min Reporting Limit	0.98	16.67	14.50	1.00	4.93	1.95	0.79	0.78	0.91
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g

U = Analyte not detected, the sample specific Method Detection Limit reported.  
J = Analyte detected below the sample specific Reporting Limit (RL).  
NA = Not applicable.  
N = QC value outside the accuracy or precision data quality objective.  
D = Result from dilution.  
B = Analyte concentration found in the sample at a concentration <3xthe level found in the procedure blank).





Project Name SPAW,  
Project Number G6001

Client Sample ID	BPB-cpsd-PAH-L	BPC-cpsd-PAH-L
Battelle Sample ID	U5840	U5841
Battelle Batch ID	03-0136	03-0136
Data File	A1697.D	A1698.D
Extraction Date	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03
Matrix	Sediment	Sediment
Sample Size (g)	21.82	22.25
Dilution Factor	1.667	1.667
PIV (mL)	1	1
Min Reporting Limit	0.76	0.75
Amount Units	ng/g	ng/g
Naphthalene	16.58	12.07
C1-Naphthalenes	9.70	7.34
C2-Naphthalenes	12.87	10.89
C3-Naphthalenes	27.75	19.76
C4-Naphthalenes	42.73	19.32
2-Methylnaphthalene	10.42	7.52
1-Methylnaphthalene	4.41	3.55
2,6-Dimethylnaphthalene	7.50	5.97
2,3,5-Trimethylnaphthalene	3.78	1.94
Biphenyl	4.65	3.15
Acenaphthylene	107.96	58.87
Acenaphthene	21.97	17.62
Fluorene	55.97	36.61
C1-Fluorenes	37.30	17.99
C2-Fluorenes	112.25	30.53
C3-Fluorenes	115.59	44.08
Phenanthrene	403.86	213.54
Anthracene	1055.09	378.74
C1-Phenanthrenes/Anthracenes	590.89	229.26
C2-Phenanthrenes/Anthracenes	910.87	243.13
C3-Phenanthrenes/Anthracenes	628.31	224.51
C4-Phenanthrenes/Anthracenes	372.43	215.16
1-Methylphenanthrene	69.41	28.14
Dibenzothiophene	19.21	11.07
C1-Dibenzothiophenes	37.67	19.04
C2-Dibenzothiophenes	116.67	32.73
C3-Dibenzothiophenes	189.09	78.65
Fluoranthene	11684.66 D	1154.37 D
Pyrene	10823.62 D	1957.40 D
C1-Fluoranthenes/Pyrenes	9474.85	3249.54
C2-Fluoranthenes/Pyrenes	3114.78	1523.76
C3-Fluoranthenes/Pyrenes	2016.86	1190.39
Benzo(a)anthracene	4264.89 D	1652.93 D
Chrysene	7033.56 D	3463.40 D
C1-Chrysenes	3400.01	1730.18
C2-Chrysenes	1830.26	964.18
C3-Chrysenes	897.21	570.59
C4-Chrysenes	453.00	352.10
Benzo(b)fluoranthene	12135.50 D	6682.10 D
Benzo(k)fluoranthene	9708.52 D	5977.29 D
Benzo(e)pyrene	6825.70 D	3860.26 D
Benzo(a)pyrene	8976.32 D	5403.57 D
Perylene	1722.81 D	1097.45 D
Indeno(1,2,3-c,d)pyrene	4413.06 D	2713.65 D
Dibenz(a,h)anthracene	1102.69 D	665.99 D
Benzo(g,h,i)perylene	3185.60 D	1971.56 D
Naphthalene-d8	75	71
Phenanthrene-d10	81	73
Chrysene-d12	121	105

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

S03-0136MSvalues.xls



Project Name SPAW,  
Project Number G6001

Client Sample ID	BPB-cpsd-PAH-L	BPC-cpsd-PAH-L
Battelle Sample ID	U5840	U5841
Battelle Batch ID	03-0136	03-0136
Data File	A1697.D	A1698.D
Extraction Date	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03
Matrix	Sediment	Sediment
Sample Size (g)	21.82	22.25
Dilution Factor	1.667	1.667
PIV (mL)	1	1
Min Reporting Limit	0.76	0.75
Amount Units	ng/g	ng/g

U = Analyte not detected, the sample  
J = Analyte detected below the samp  
NA = Not applicable.  
N = QC value outside the accuracy o  
D = Result from dilution.  
B = Analyte concentration found in th



Project Name SPAW,  
Project Number G6001

Client Sample ID	SLA-cpsd-PAH-U	SLB-cpsd-PAH-U	SLC-cpsd-PAH-U	SLA-cpsd-PAH-L	SLB-cpsd-PAH-L	SLC-cpsd-PAH-L
Battelle Sample ID	U5842	U5843	U5844	U5845	U5846	U5847
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1699.D	A1701.D	A1702.D	A1703.D	A1704.D	A1705.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	17.97	17.13	17.63	18.46	17.59	17.69
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	0.93	0.97	0.95	0.90	0.95	0.94
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene	13.16	13.12	111.61	16.95	15.93	22.90
C1-Naphthalenes	7.86	8.18	31.19	9.12	8.55	102.08
C2-Naphthalenes	36.13	43.63	88.00	23.29	23.25	229.25
C3-Naphthalenes	79.54	156.72	318.93	58.43	57.71	983.77
C4-Naphthalenes	115.66	460.79	1420.12	56.25	261.94	2845.63
2-Methylnaphthalene	8.25	7.84	24.97	9.32	7.95	124.41
1-Methylnaphthalene	3.49	4.34	19.83	4.35	4.65	33.18
2,6-Dimethylnaphthalene	9.68	11.34	20.48	8.08	9.10	67.05
2,3,5-Trimethylnaphthalene	8.90	36.27	70.44	4.11	10.11	290.21
Biphenyl	4.07	4.57	10.91	3.74	5.66	65.85
Acenaphthylene	57.91	119.40	36.71	46.15	74.97	24.38
Acenaphthene	174.55	123.30	295.76	12.87	24.66	361.34
Fluorene	64.73	138.29	209.67	15.21	49.90	1430.56 D
C1-Fluorenes	82.93	177.19	152.77	40.20	55.77	205.01
C2-Fluorenes	205.73	441.78	671.55	93.62	141.32	1303.92
C3-Fluorenes	338.08	586.73	1767.53	346.93	380.55	2906.92
Phenanthrene	388.97	2997.00 D	477.92	129.49	222.56	2704.03 D
Anthracene	257.04	531.60	256.31	121.94	244.72	5135.82 D
C1-Phenanthrenes/Anthracenes	260.42	2043.82	484.30	113.00	205.00	801.99
C2-Phenanthrenes/Anthracenes	305.29	2265.36	1367.99	169.49	283.43	2848.25
C3-Phenanthrenes/Anthracenes	333.79	1581.85	1914.40	206.48	424.94	3717.23
C4-Phenanthrenes/Anthracenes	1012.57	2382.72	2898.15	785.33	984.38	3621.93
1-Methylphenanthrene	29.77	543.11 D	37.39	10.81	20.10	132.09
Dibenzothiophene	30.61	146.32	55.27	7.33	11.97	38.31
C1-Dibenzothiophenes	78.78	265.70	171.86	42.28	54.09	317.97
C2-Dibenzothiophenes	123.75	696.51	1177.31	104.53	219.81	2724.29
C3-Dibenzothiophenes	536.37	1495.12	2938.28	534.79	683.09	4985.06
Fluoranthene	1685.10 D	29347.18 D	1384.26 D	372.19	777.49	1843.33 D
Pyrene	4411.51 D	25918.78 D	3235.20 D	2029.57 D	2401.72 D	2966.20 D
C1-Fluoranthenes/Pyrenes	2326.10	6303.78	2512.62	1391.92	2396.00	2236.82
C2-Fluoranthenes/Pyrenes	1624.19	5500.83	2230.99	1335.76	1581.98	2224.96
C3-Fluoranthenes/Pyrenes	1573.84	2334.44	2190.79	1301.12	1499.00	2242.05
Benzo(a)anthracene	889.07 D	5343.35 D	1042.18 D	367.75	988.26 D	758.99
Chrysene	1632.91 D	7190.68 D	1470.57 D	665.77	1788.73 D	1393.77 D
C1-Chrysenes	912.54	2076.39	1190.92	611.64	827.05	980.12
C2-Chrysenes	949.67	1231.54	1357.61	638.95	955.31	1490.65
C3-Chrysenes	997.60	1128.19	1247.34	814.18	931.52	1162.68
C4-Chrysenes	775.35	734.66	891.20	555.86	642.80	706.97
Benzo(b)fluoranthene	3839.81 D	5608.44 D	2147.77 D	3133.49 D	4693.99 D	931.23 D
Benzo(k)fluoranthene	3085.60 D	5460.42 D	1896.35 D	2560.45 D	3872.56 D	615.37
Benzo(e)pyrene	2076.05 D	3452.24 D	1392.12 D	1559.45 D	2135.98 D	587.41
Benzo(a)pyrene	2876.75 D	3906.02 D	1674.11 D	2322.93 D	3475.23 D	670.11
Perylene	723.61 D	926.14 D	495.49	511.50	757.71 D	264.25
Indeno(1,2,3-c,d)pyrene	1334.61 D	1766.85 D	909.58	1115.56 D	1703.42 D	362.53
Dibenz(a,h)anthracene	357.83 D	439.57 D	243.20	439.27	469.58 D	107.09
Benzo(g,h,i)perylene	1033.89 D	1426.24 D	625.69	825.30	1259.98 D	281.28
Naphthalene-d8	47	44	55	47	52	50
Phenanthrene-d10	60	63	66	59	63	55
Chrysene-d12	74	81	90	73	79	77



Project Name SPAW,  
Project Number G6001

Client Sample ID	SLA-cpsd-PAH-U	SLB-cpsd-PAH-U	SLC-cpsd-PAH-U	SLA-cpsd-PAH-L	SLB-cpsd-PAH-L	SLC-cpsd-PAH-L
Battelle Sample ID	U5842	U5843	U5844	U5845	U5846	U5847
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1699.D	A1701.D	A1702.D	A1703.D	A1704.D	A1705.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	17.97	17.13	17.63	18.46	17.59	17.69
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	0.93	0.97	0.95	0.90	0.95	0.94
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g

U = Analyte not detected, the sample  
J = Analyte detected below the samp  
NA = Not applicable.  
N = QC value outside the accuracy o  
D = Result from dilution.  
B = Analyte concentration found in th



Project Name SPAW,  
Project Number G6001

Client Sample ID	BPA-STs-PAH	BPB-STs-PAH	BPC-STs-PAH	SLA-STs-PAH	SLB-STs-PAH	SLC-STs-PAH
Battelle Sample ID	U5848	U5849	U5850	U5851	U5852	U5853
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1706.D	A1708.D	A1709.D	A1710.D	A1711.D	A1712.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	7.37	10.59	5.32	8.33	3.5	2.53
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	2.26	1.57	3.13	2.00	4.76	6.59
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Naphthalene	44.98	42.78	54.14	29.29	28.71	25.53
C1-Naphthalenes	153.10	213.33	151.07	66.92	65.95	47.88
C2-Naphthalenes	277.30	371.93	280.92	136.60	112.58	97.74
C3-Naphthalenes	248.09	320.63	254.24	176.83	139.56	128.70
C4-Naphthalenes	124.13	163.95	127.91	179.02	86.07	98.83
2-Methylnaphthalene	168.89	227.87	160.26	72.24	71.99	52.37
1-Methylnaphthalene	67.12	100.50	70.54	30.26	29.04	20.85
2,6-Dimethylnaphthalene	166.28	209.95	164.28	83.10	80.15	76.71
2,3,5-Trimethylnaphthalene	53.89	71.19	54.87	40.04	21.27	17.92
Biphenyl	112.47	205.63	110.59	28.57	29.34	15.74
Acenaphthylene	93.18	87.59	69.17	34.98	42.18	34.74
Acenaphthene	826.21	1668.66	950.01	257.07	177.78	68.86
Fluorene	1762.62	3778.53 D	1911.61	504.13	384.76	257.65
C1-Fluorenes	431.56	670.81	454.71	208.46	131.56	88.41
C2-Fluorenes	325.80	421.88	289.08	267.92	179.53	139.57
C3-Fluorenes	196.70	213.82	187.38	189.79	124.76	86.84
Phenanthrene	13980.48 D	26573.77 D	13745.14 D	2894.82 D	2025.82	1560.38
Anthracene	4116.36 D	4454.78 D	2724.67	1246.30	802.04	882.77
C1-Phenanthrenes/Anthracenes	3275.92	4581.07	3124.12	1163.42	771.74	598.03
C2-Phenanthrenes/Anthracenes	1533.28	2016.69	1359.97	738.63	470.91	382.46
C3-Phenanthrenes/Anthracenes	640.87	789.92	513.26	394.50	224.00	200.09
C4-Phenanthrenes/Anthracenes	356.28	330.11	248.63	412.56	255.61	233.68
1-Methylphenanthrene	618.04	868.18	592.82	211.97	150.47	115.94
Dibenzothiophene	646.53	1206.33	661.57	125.16	101.45	74.34
C1-Dibenzothiophenes	296.21	424.72	289.11	137.15	105.06	85.85
C2-Dibenzothiophenes	252.40	323.50	214.17	206.06	138.94	129.06
C3-Dibenzothiophenes	215.62	277.23	162.10	348.86	207.39	185.83
Fluoranthene	20263.93 D	30683.19 D	18876.27 D	4854.87 D	2763.34	3120.13
Pyrene	12855.89 D	18811.13 D	11571.86 D	3152.21 D	1958.47	2023.36
C1-Fluoranthenes/Pyrenes	7490.08	9680.55	6309.62	2673.50	1728.89	1695.73
C2-Fluoranthenes/Pyrenes	2843.69	3680.53	2081.82	1195.93	826.63	800.19
C3-Fluoranthenes/Pyrenes	1250.32	1582.97	811.80	825.76	613.29	552.46
Benzo(a)anthracene	7252.92 D	8623.69 D	5902.97 D	1643.91	1076.60	1210.44
Chrysene	12061.50 D	14257.18 D	9444.40 D	2562.98 D	1697.68	1907.06
C1-Chrysenes	2800.87	3208.38	1899.71	824.90	601.35	560.69
C2-Chrysenes	1156.97	1344.28	715.74	558.29	460.66	415.76
C3-Chrysenes	634.92	699.25	377.40	489.45	538.10	389.70
C4-Chrysenes	325.25	356.03	188.35	365.28	373.57	307.00
Benzo(b)fluoranthene	7990.99 D	8393.87 D	5326.10 D	2113.97 D	2027.39	2187.71
Benzo(k)fluoranthene	6717.83 D	7537.23 D	4857.96 D	1669.18	1638.96	1750.60
Benzo(e)pyrene	4783.18 D	5516.37 D	3300.52	1317.05	1300.51	1377.97
Benzo(a)pyrene	4868.57 D	5344.47 D	3439.24	1465.61	1285.25	1460.79
Perylene	1578.55	1475.59 D	1033.68	422.86	398.59	446.54
Indeno(1,2,3-c,d)pyrene	3178.07 D	3170.92 D	2923.14	1140.33	1347.84	1435.93
Dibenz(a,h)anthracene	1541.58	737.64 D	747.29	296.15	318.26	330.93
Benzo(g,h,i)perylene	2811.57	2440.21 D	1921.91	867.71	951.17	1023.58
Naphthalene-d8	76	54	77	72	75	71
Phenanthrene-d10	70	76	72	72	71	68
Chrysene-d12	77	87	70	79	70	62



Project Name SPAW,  
Project Number G6001

Client Sample ID	BPA-STs-PAH	BPB-STs-PAH	BPC-STs-PAH	SLA-STs-PAH	SLB-STs-PAH	SLC-STs-PAH
Battelle Sample ID	U5848	U5849	U5850	U5851	U5852	U5853
Battelle Batch ID	03-0136	03-0136	03-0136	03-0136	03-0136	03-0136
Data File	A1706.D	A1708.D	A1709.D	A1710.D	A1711.D	A1712.D
Extraction Date	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03	02/14/03
Acquired Date	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03	02/27/03
Matrix	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
Sample Size (g)	7.37	10.59	5.32	8.33	3.5	2.53
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV (mL)	1	1	1	1	1	1
Min Reporting Limit	2.26	1.57	3.13	2.00	4.76	6.59
Amount Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g

U = Analyte not detected, the sample  
J = Analyte detected below the samp  
NA = Not applicable.  
N = QC value outside the accuracy o  
D = Result from dilution.  
B = Analyte concentration found in th



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample Bay	Water Spilled with FW21	BPA-cppw-PAH-U	BPB-cppw-PAH-U	BPC-cppw-PAH-U
Battelle Sample ID	AB666PB-R1	AB667LCS-R1	AB671SRM	U1611	U1612	U1613
Battelle Batch ID	02-727	02-727	02-727	02-727	02-727	02-727
Data File	A1088.D	A1089.D	A1090.D	A1091.D	A1092.D	A1094.D
Extraction Date	12/16/02	12/16/02	12/16/02	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	1.075 L	1.04 L	1.04 L
Dilution Factor	4.167	4.167	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	41.67	41.67	16.67	15.51	16.03	16.03
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	9.88 J	830.40	705.61	15.09 J	54.18	65.11
C1-Naphthalenes	83.84 U	83.84 U	33.54 U	13.55 J	74.82	59.64
C2-Naphthalenes	83.84 U	83.84 U	33.54 U	17.52	48.65	28.61
C3-Naphthalenes	83.84 U	83.84 U	33.54 U	8.11 J	15.47 J	8.94 J
C4-Naphthalenes	83.84 U	83.84 U	33.54 U	31.20 U	32.25 U	32.25 U
2-Methylnaphthalene	2.48 U	809.69	663.97	12.02 J	68.38	55.25
1-Methylnaphthalene	2.57 U	821.07	722.08	8.39 J	50.99	40.49
2,6-Dimethylnaphthalene	2.37 U	816.86	699.12	6.23 J	18.63	10.08 J
2,3,5-Trimethylnaphthalene	2.49 U	708.18	558.46	2.05 J	4.57 J	2.28 J
Biphenyl	2.08 U	793.23	676.10	5.54 J	26.69	20.73
Acenaphthylene	2.07 U	818.86	697.96	6.16 J	9.23 J	9.02 J
Acenaphthene	2.68 U	848.15	761.10	89.32	461.90	275.17
Fluorene	2.45 U	864.32	774.95	50.43	293.22	154.50
C1-Fluorenes	2.45 U	2.45 U	0.98 U	12.79 J	29.57	13.21 J
C2-Fluorenes	2.45 U	2.45 U	0.98 U	0.91 U	9.97 J	0.94 U
C3-Fluorenes	2.45 U	2.45 U	0.98 U	0.91 U	18.21	0.94 U
Phenanthrene	1.88 U	861.82	824.71	230.28	981.41	344.04
Anthracene	1.74 U	774.10	563.46	50.99	139.66	69.69
C1-Phenanthrenes/Anthracenes	1.88 U	1.88 U	0.75 U	67.87	138.92	49.91
C2-Phenanthrenes/Anthracenes	1.88 U	1.88 U	0.75 U	24.14	30.31	14.01 J
C3-Phenanthrenes/Anthracenes	1.88 U	1.88 U	0.75 U	15.03 J	18.30	9.01 J
C4-Phenanthrenes/Anthracenes	1.88 U	1.88 U	0.75 U	26.77	0.72 U	0.72 U
1-Methylphenanthrene	2.16 U	859.99	836.37	14.45 J	28.40	9.07 J
Dibenzothiophene	2.32 U	12.13 J	5.38 J	17.77	63.44	26.03
C1-Dibenzothiophenes	2.32 U	2.32 U	0.93 U	7.21 J	15.48 J	7.12 J
C2-Dibenzothiophenes	2.32 U	2.32 U	0.93 U	8.14 J	7.92 J	0.89 U
C3-Dibenzothiophenes	2.32 U	2.32 U	0.93 U	0.86 U	0.89 U	0.89 U
Fluoranthene	2.20 U	904.07	893.85	423.67	970.18	348.47
Pyrene	2.39 U	914.28	945.87	440.74	733.29	362.03
C1-Fluoranthenes/Pyrenes	2.20 U	2.20 U	0.88 U	256.67	330.05	154.26
C2-Fluoranthenes/Pyrenes	2.20 U	2.20 U	0.88 U	101.99	103.59	50.25
C3-Fluoranthenes/Pyrenes	2.20 U	2.20 U	0.88 U	31.20	29.32	14.27 J
Benzo(a)anthracene	3.47 U	888.86	709.93	120.24	184.24	71.60
Chrysene	1.83 U	917.57	856.04	229.47	330.71	138.34
C1-Chrysenes	1.83 U	1.83 U	0.73 U	112.98	112.06	53.14
C2-Chrysenes	1.83 U	1.83 U	0.73 U	70.09	65.19	26.61
C3-Chrysenes	1.83 U	1.83 U	0.73 U	32.50	23.03	0.70 U
C4-Chrysenes	1.83 U	1.83 U	0.73 U	0.68 U	0.70 U	0.70 U



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample Bay	Water Spilled with FW21	BPA-cppw-PAH-U	BPB-cppw-PAH-U	BPC-cppw-PAH-U
Battelle Sample ID	AB666PB-R1	AB667LCS-R1	AB671SRM	U1611	U1612	U1613
Battelle Batch ID	02-727	02-727	02-727	02-727	02-727	02-727
Data File	A1088.D	A1089.D	A1090.D	A1091.D	A1092.D	A1094.D
Extraction Date	12/16/02	12/16/02	12/16/02	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	1.075 L	1.04 L	1.04 L
Dilution Factor	4.167	4.167	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	41.67	41.67	16.67	15.51	16.03	16.03
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	2.15 U	912.91	833.35	425.34	516.90	207.06
Benzo(k)fluoranthene	2.17 U	944.78	856.24	377.53	419.73	186.37
Benzo(e)pyrene	2.27 U	925.24	883.69	330.58	357.94	172.82
Benzo(a)pyrene	3.25 U	851.32	757.12	344.22	380.20	176.24
Perylene	3.49 U	769.98	615.81	88.19	90.07	38.50
Indeno(1,2,3-c,d)pyrene	4.56 U	928.07	774.09	208.40	229.77	94.97
Dibenz(a,h)anthracene	5.21 U	961.41	642.31	48.94	52.11	23.00
Benzo(g,h,i)perylene	2.83 U	847.03	697.21	145.08	155.35	74.15
Naphthalene-d8	81	94	78	66	81	67
Phenanthrene-d10	72	84	74	70	80	75
Chrysene-d12	82	99	85	81	89	84

U = Analyte not detected, the sample specific Method Detection Limit reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.





Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPA-cppw-PAH-L	BPB-cppw-PAH-L	BPC-cppw-PAH-L
Battelle Sample ID	U1614	U1615	U1616
Battelle Batch ID	02-727	02-727	02-727
Data File	A1095.D	A1096.D	A1097.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	1 L	0.8 L	0.7 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	20.84	23.81
Amount Units	ng/L	ng/L	ng/L
Naphthalene	10.94 J	14.36 J	32.17
C1-Naphthalenes	4.68 J	8.36 J	23.55 J
C2-Naphthalenes	3.75 J	6.36 J	12.50 J
C3-Naphthalenes	33.54 U	41.93 U	47.92 U
C4-Naphthalenes	33.54 U	41.93 U	47.92 U
2-Methylnaphthalene	3.85 J	6.33 J	18.72 J
1-Methylnaphthalene	2.58 J	5.33 J	18.08 J
2,6-Dimethylnaphthalene	1.57 J	1.85 J	4.48 J
2,3,5-Trimethylnaphthalene	1.00 U	1.25 U	1.42 U
Biphenyl	1.30 J	2.29 J	7.95 J
Acenaphthylene	3.57 J	2.75 J	3.98 J
Acenaphthene	3.55 J	18.96 J	87.49
Fluorene	2.95 J	8.61 J	45.01
C1-Fluorenes	0.98 U	1.23 U	3.74 J
C2-Fluorenes	0.98 U	1.23 U	1.40 U
C3-Fluorenes	0.98 U	1.23 U	1.40 U
Phenanthrene	17.82	20.21 J	68.49
Anthracene	7.72 J	21.63	12.41 J
C1-Phenanthrenes/Anthracenes	12.75 J	7.21 J	11.15 J
C2-Phenanthrenes/Anthracenes	10.34 J	0.94 U	1.07 U
C3-Phenanthrenes/Anthracenes	7.78 J	0.94 U	1.07 U
C4-Phenanthrenes/Anthracenes	0.75 U	0.94 U	1.07 U
1-Methylphenanthrene	2.80 J	1.52 J	2.74 J
Dibenzothiophene	2.08 J	1.98 J	5.57 J
C1-Dibenzothiophenes	0.93 U	1.16 U	1.32 U
C2-Dibenzothiophenes	0.93 U	1.16 U	1.32 U
C3-Dibenzothiophenes	0.93 U	1.16 U	1.32 U
Fluoranthene	99.89	37.40	60.37
Pyrene	377.11	84.23	84.87
C1-Fluoranthenes/Pyrenes	215.63	66.45	72.04
C2-Fluoranthenes/Pyrenes	92.22	27.88	39.77
C3-Fluoranthenes/Pyrenes	37.19	12.65 J	17.53 J
Benzo(a)anthracene	50.08	15.11 J	19.60 J
Chrysene	109.32	37.28	46.10
C1-Chrysenes	81.85	24.63	32.96
C2-Chrysenes	57.09	0.91 U	19.48 J
C3-Chrysenes	24.54	0.91 U	1.05 U
C4-Chrysenes	0.73 U	0.91 U	1.05 U



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPA-cppw-PAH-L	BPB-cppw-PAH-L	BPC-cppw-PAH-L
Battelle Sample ID	U1614	U1615	U1616
Battelle Batch ID	02-727	02-727	02-727
Data File	A1095.D	A1096.D	A1097.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	1 L	0.8 L	0.7 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	20.84	23.81
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	402.21	177.62	200.64
Benzo(k)fluoranthene	357.10	154.80	194.11
Benzo(e)pyrene	312.35	116.09	147.93
Benzo(a)pyrene	335.55	135.96	176.87
Perylene	67.80	12.92 J	18.36 J
Indeno(1,2,3-c,d)pyrene	160.90	61.07	83.18
Dibenz(a,h)anthracene	36.01	13.57 J	18.17 J
Benzo(g,h,i)perylene	119.24	50.93	64.56
Naphthalene-d8	69	71	69
Phenanthrene-d10	72	72	74
Chrysene-d12	81	80	81

U = Analyte not detected, the sample specific Meth

J = Analyte detected below the sample specific Re

NA = Not applicable.

N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLA-cppw-PAH-U	SLB-cppw-PAH-U	SLC-cppw-PAH-U
Battelle Sample ID	U1617	U1618	U1619
Battelle Batch ID	02-727	02-727	02-727
Data File	A1098.D	A1100.D	A1101.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	1.05 L	1.075 L	1.02 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	15.88	15.51	16.34
Amount Units	ng/L	ng/L	ng/L
Naphthalene	9.21 J	8.25 J	1789.85
C1-Naphthalenes	5.64 J	8.62 J	219.03
C2-Naphthalenes	14.65 J	42.60	522.57
C3-Naphthalenes	37.47	372.85	1681.17
C4-Naphthalenes	17.35	487.68	2803.68
2-Methylnaphthalene	3.45 J	4.73 J	166.81
1-Methylnaphthalene	4.33 J	8.75 J	184.55
2,6-Dimethylnaphthalene	3.45 J	6.81 J	107.57
2,3,5-Trimethylnaphthalene	11.10 J	96.11	487.70
Biphenyl	0.79 U	2.09 J	44.16
Acenaphthylene	2.62 J	3.13 J	21.97
Acenaphthene	37.12	170.64	2046.50
Fluorene	40.04	32.98	1220.90
C1-Fluorenes	36.07	58.41	414.81
C2-Fluorenes	37.98	390.03	2359.41
C3-Fluorenes	62.79	381.13	2608.38
Phenanthrene	345.88	100.21	1455.52
Anthracene	57.68	59.22	265.90
C1-Phenanthrenes/Anthracenes	175.27	230.59	1144.90
C2-Phenanthrenes/Anthracenes	65.17	1095.97	7667.15
C3-Phenanthrenes/Anthracenes	63.66	1113.62	9917.21
C4-Phenanthrenes/Anthracenes	54.01	296.59	2914.95
1-Methylphenanthrene	40.74	37.36	159.00
Dibenzothiophene	19.85	13.58 J	221.32
C1-Dibenzothiophenes	19.77	63.86	431.95
C2-Dibenzothiophenes	47.98	1607.58	7858.42
C3-Dibenzothiophenes	192.94	2697.13	15265.62
Fluoranthene	424.23	1069.21	2822.57
Pyrene	868.17	1563.24	5285.06
C1-Fluoranthenes/Pyrenes	389.95	1082.91	6182.87
C2-Fluoranthenes/Pyrenes	253.11	836.46	7012.37
C3-Fluoranthenes/Pyrenes	198.93	645.97	5999.45
Benzo(a)anthracene	73.48	349.31	1376.75
Chrysene	83.87	367.84	1480.03
C1-Chrysenes	91.42	386.17	3147.79
C2-Chrysenes	128.87	496.07	4906.37
C3-Chrysenes	123.71	359.22	3783.21
C4-Chrysenes	45.95	97.06	992.27



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLA-cppw-PAH-U	SLB-cppw-PAH-U	SLC-cppw-PAH-U
Battelle Sample ID	U1617	U1618	U1619
Battelle Batch ID	02-727	02-727	02-727
Data File	A1098.D	A1100.D	A1101.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	1.05 L	1.075 L	1.02 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	15.88	15.51	16.34
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	320.35	377.16	1270.63
Benzo(k)fluoranthene	289.66	331.54	985.49
Benzo(e)pyrene	201.82	297.01	1203.79
Benzo(a)pyrene	262.00	300.06	814.72
Perylene	56.68	93.74	563.92
Indeno(1,2,3-c,d)pyrene	82.73	106.27	461.24
Dibenz(a,h)anthracene	20.61	31.49	144.75
Benzo(g,h,i)perylene	67.85	99.97	511.16
Naphthalene-d8	64	72	79
Phenanthrene-d10	78	80	81
Chrysene-d12	84	87	89

U = Analyte not detected, the sample specific Meth  
J = Analyte detected below the sample specific Re  
NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLA-cppw-PAH-L	SLB-cppw-PAH-L	SLC-cppw-PAH-L
Battelle Sample ID	U1620	U1621	U1622
Battelle Batch ID	02-727	02-727	02-727
Data File	A1102.D	A1103.D	A1104.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	0.88 L	1.025 L	0.9 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	18.94	16.26	18.52
Amount Units	ng/L	ng/L	ng/L
Naphthalene	11.06 J	7.71 J	107.28
C1-Naphthalenes	5.08 J	6.00 J	356.13
C2-Naphthalenes	6.48 J	10.41 J	2877.02
C3-Naphthalenes	4.39 J	43.81	12872.63
C4-Naphthalenes	38.12 U	109.70	15061.70
2-Methylnaphthalene	4.11 J	3.16 J	132.92
1-Methylnaphthalene	2.78 J	6.03 J	463.02
2,6-Dimethylnaphthalene	1.08 U	1.77 J	768.75
2,3,5-Trimethylnaphthalene	1.13 U	15.86 J	3869.05
Biphenyl	0.95 U	3.43 J	119.54
Acenaphthylene	1.99 J	1.77 J	54.20
Acenaphthene	3.18 J	32.45	4622.74
Fluorene	1.86 J	10.03 J	2655.10
C1-Fluorenes	2.18 J	9.77 J	2048.59
C2-Fluorenes	13.05 J	69.88	10995.83
C3-Fluorenes	34.29	91.74	11528.10
Phenanthrene	3.62 J	20.38	3477.68
Anthracene	1.70 J	4.86 J	1154.05
C1-Phenanthrenes/Anthracenes	6.25 J	23.52	6963.73
C2-Phenanthrenes/Anthracenes	14.51 J	186.33	40105.72
C3-Phenanthrenes/Anthracenes	35.84	238.71	38467.40
C4-Phenanthrenes/Anthracenes	27.98	86.68	8668.25
1-Methylphenanthrene	0.97 J	4.23 J	1122.91
Dibenzothiophene	1.63 J	3.77 J	758.95
C1-Dibenzothiophenes	4.09 J	12.67 J	2970.30
C2-Dibenzothiophenes	35.52	309.31	42863.59
C3-Dibenzothiophenes	173.52	638.53	72152.93
Fluoranthene	35.67	139.30	14213.01
Pyrene	340.11	476.39	22569.25
C1-Fluoranthenes/Pyrenes	222.64	301.33	24724.54
C2-Fluoranthenes/Pyrenes	182.78	274.97	26503.32
C3-Fluoranthenes/Pyrenes	149.01	216.58	21336.53
Benzo(a)anthracene	27.18	64.71	6540.66
Chrysene	32.81	76.44	7060.37
C1-Chrysenes	73.40	111.08	12061.02
C2-Chrysenes	97.42	157.93	18510.72
C3-Chrysenes	93.50	130.61	13340.43
C4-Chrysenes	0.83 U	45.88	3577.81



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLA-cppw-PAH-L	SLB-cppw-PAH-L	SLC-cppw-PAH-L
Battelle Sample ID	U1620	U1621	U1622
Battelle Batch ID	02-727	02-727	02-727
Data File	A1102.D	A1103.D	A1104.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/18/03	01/18/03
Matrix	Water	Water	Water
Sample Size	0.88 L	1.025 L	0.9 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	18.94	16.26	18.52
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	278.10	228.26	5570.56
Benzo(k)fluoranthene	223.38	203.62	4410.36
Benzo(e)pyrene	146.54	146.91	5078.96
Benzo(a)pyrene	189.19	173.22	3585.40
Perylene	41.81	45.18	2147.56
Indeno(1,2,3-c,d)pyrene	69.58	66.19	2096.14
Dibenz(a,h)anthracene	19.68	18.33	658.50
Benzo(g,h,i)perylene	61.87	56.87	2169.19
Naphthalene-d8	71	56	75
Phenanthrene-d10	76	70	73
Chrysene-d12	83	76	86

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NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLB-cppw-PAH-U (BOTTLE 2)	SLC-cppw-PAH-U (BOTTLE 2)	SLB-cppw-PAH-L (BOTTLE 2)
Battelle Sample ID	U1623	U1624	U1625
Battelle Batch ID	02-727	02-727	02-727
Data File	A1106.D	A1107.D	A1108.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.9 L	0.6 L	0.32 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	18.52	27.78	52.09
Amount Units	ng/L	ng/L	ng/L
Naphthalene	13.28 J	1730.62	27.09 J
C1-Naphthalenes	10.80 J	209.54	18.02 J
C2-Naphthalenes	54.38	468.76	22.24 J
C3-Naphthalenes	419.10	1488.41	55.74
C4-Naphthalenes	526.42	2159.74	101.06
2-Methylnaphthalene	5.70 J	164.62	11.77 J
1-Methylnaphthalene	10.09 J	178.67	14.53 J
2,6-Dimethylnaphthalene	9.37 J	94.82	9.27 J
2,3,5-Trimethylnaphthalene	107.73	384.38	19.07 J
Biphenyl	2.32 J	41.15	9.01 J
Acenaphthylene	3.39 J	20.28 J	3.59 J
Acenaphthene	181.81	1892.35	40.06 J
Fluorene	37.32	1114.50	13.18 J
C1-Fluorenes	68.42	341.62	11.20 J
C2-Fluorenes	420.07	1853.20	69.28
C3-Fluorenes	405.23	2042.63	107.68
Phenanthrene	138.82	1289.45	24.85 J
Anthracene	64.66	300.64	8.07 J
C1-Phenanthrenes/Anthracenes	259.76	991.48	33.08 J
C2-Phenanthrenes/Anthracenes	1278.66	6589.23	122.84
C3-Phenanthrenes/Anthracenes	1304.39	7697.34	299.49
C4-Phenanthrenes/Anthracenes	341.46	2060.19	112.21
1-Methylphenanthrene	41.05	136.08	54.13
Dibenzothiophene	18.13 J	198.29	6.09 J
C1-Dibenzothiophenes	76.22	347.24	12.55 J
C2-Dibenzothiophenes	1897.42	6666.00	312.20
C3-Dibenzothiophenes	3254.35	12709.85	711.03
Fluoranthene	1288.18	2498.00	152.69
Pyrene	1907.70	4750.51	555.58
C1-Fluoranthenes/Pyrenes	1336.69	5306.92	370.23
C2-Fluoranthenes/Pyrenes	1073.33	5966.92	351.16
C3-Fluoranthenes/Pyrenes	780.14	4769.26	295.94
Benzo(a)anthracene	425.88	1182.79	83.04
Chrysene	458.85	1270.81	100.80
C1-Chrysenes	515.55	2563.37	141.28
C2-Chrysenes	670.58	4189.00	234.94
C3-Chrysenes	475.06	3233.67	233.90
C4-Chrysenes	115.50	814.52	2.29 U

Not Surrogate Corrected  
Final results

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6/20/2006

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Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLB-cppw-PAH-U (BOTTLE 2)	SLC-cppw-PAH-U (BOTTLE 2)	SLB-cppw-PAH-L (BOTTLE 2)
Battelle Sample ID	U1623	U1624	U1625
Battelle Batch ID	02-727	02-727	02-727
Data File	A1106.D	A1107.D	A1108.D
Extraction Date	12/16/02	12/16/02	12/16/02
Acquired Date	01/18/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.9 L	0.6 L	0.32 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	18.52	27.78	52.09
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	535.64	1041.12	337.57
Benzo(k)fluoranthene	439.55	784.27	283.18
Benzo(e)pyrene	394.71	1034.73	203.43
Benzo(a)pyrene	339.92	728.37	264.48
Perylene	121.12	498.35	63.71
Indeno(1,2,3-c,d)pyrene	169.39	402.61	91.53
Dibenz(a,h)anthracene	49.16	130.33	22.56 J
Benzo(g,h,i)perylene	149.77	435.23	76.16
Naphthalene-d8	70	73	65
Phenanthrene-d10	76	74	73
Chrysene-d12	83	80	81

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Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	DB-Water2 Matrix Spike	DB-Water2 Matrix Spike Duplicate	Duxbury Water
Battelle Sample ID	U1817MS-1	U1817MSD-1	U2211
Battelle Batch ID	02-727	02-727	02-739
Data File	A1109.D	A1110.D	A1180.D
Extraction Date	12/16/02	12/16/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/22/03
Matrix	Water	Water	Water
Sample Size	0.95 L	0.95 L	1.00 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1.00 mL
Min Reporting Limit	17.55	17.55	16.67
Amount Units	ng/L	ng/L	ng/L
Naphthalene	756.41	762.24	14.24 J
C1-Naphthalenes	35.31 U	35.31 U	7.67 J
C2-Naphthalenes	35.31 U	35.31 U	33.54 U
C3-Naphthalenes	35.31 U	35.31 U	33.54 U
C4-Naphthalenes	35.31 U	35.31 U	33.54 U
2-Methylnaphthalene	689.31	702.81	6.83 J
1-Methylnaphthalene	698.79	717.35	4.50 J
2,6-Dimethylnaphthalene	658.38	669.73	0.95 U
2,3,5-Trimethylnaphthalene	602.91	624.23	1.00 U
Biphenyl	683.79	688.61	1.75 J
Acenaphthylene	745.83	756.10	0.82 J
Acenaphthene	752.78	764.73	1.05 J
Fluorene	780.23	805.95	1.47 J
C1-Fluorenes	1.03 U	1.03 U	0.98 U
C2-Fluorenes	1.03 U	1.03 U	0.98 U
C3-Fluorenes	1.03 U	1.03 U	0.98 U
Phenanthrene	815.86	821.55	5.72 J
Anthracene	707.63	709.37	0.70 U
C1-Phenanthrenes/Anthracenes	0.79 U	0.79 U	0.75 U
C2-Phenanthrenes/Anthracenes	0.79 U	0.79 U	0.75 U
C3-Phenanthrenes/Anthracenes	0.79 U	0.79 U	0.75 U
C4-Phenanthrenes/Anthracenes	0.79 U	0.79 U	0.75 U
1-Methylphenanthrene	792.91	787.16	0.87 U
Dibenzothiophene	11.02 J	11.00 J	2.50 J
C1-Dibenzothiophenes	0.98 U	0.98 U	0.93 U
C2-Dibenzothiophenes	0.98 U	0.98 U	0.93 U
C3-Dibenzothiophenes	0.98 U	0.98 U	0.93 U
Fluoranthene	878.81	881.04	5.62 J
Pyrene	873.54	871.74	4.95 J
C1-Fluoranthenes/Pyrenes	14.74 J	15.37 J	0.88 U
C2-Fluoranthenes/Pyrenes	0.93 U	0.93 U	0.88 U
C3-Fluoranthenes/Pyrenes	0.93 U	0.93 U	0.88 U
Benzo(a)anthracene	780.49	771.24	1.07 J
Chrysene	858.01	858.49	3.38 J
C1-Chrysenes	7.32 J	7.51 J	0.73 U
C2-Chrysenes	0.77 U	0.77 U	0.73 U
C3-Chrysenes	0.77 U	0.77 U	0.73 U
C4-Chrysenes	0.77 U	0.77 U	0.73 U

Not Surrogate Corrected  
Final results

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6/20/2006

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Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	DB-Water2 Matrix Spike	DB-Water2 Matrix Spike Duplicate	Duxbury Water
Battelle Sample ID	U1817MS-1	U1817MSD-1	U2211
Battelle Batch ID	02-727	02-727	02-739
Data File	A1109.D	A1110.D	A1180.D
Extraction Date	12/16/02	12/16/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/22/03
Matrix	Water	Water	Water
Sample Size	0.95 L	0.95 L	1.00 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1.00 mL
Min Reporting Limit	17.55	17.55	16.67
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	822.01	808.20	0.86 U
Benzo(k)fluoranthene	859.52	873.46	0.87 U
Benzo(e)pyrene	862.17	855.03	0.91 U
Benzo(a)pyrene	800.95	793.14	1.30 U
Perylene	769.77	758.77	1.40 U
Indeno(1,2,3-c,d)pyrene	754.92	757.34	1.83 U
Dibenz(a,h)anthracene	808.72	786.84	2.09 U
Benzo(g,h,i)perylene	759.34	752.90	1.98 J
Naphthalene-d8	74	75	55
Phenanthrene-d10	70	70	73
Chrysene-d12	79	79	80

U = Analyte not detected, the sample specific Meth  
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NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Lab Control Sample Bay Water Spilled with FW21	SLC-BFSD2-F1-PAHs	SLC-BFSD2-F2-PAHs	SLC-BFSD2-F3-PAHs	
Battelle Sample ID	AB704PB	AB705LCS	AB705SRM	U2104	U2105	U2106
Battelle Batch ID	02-739	02-739	02-739	02-739	02-739	02-739
Data File	A1112.D	A1113.D	A1114.D	A1115.D	A1116.D	A1117.D
Extraction Date	12/20/02	12/20/02	12/20/02	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	0.21 L	0.23 L	0.23 L
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	16.67	16.67	79.38	72.48	72.48
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	4.05 J	754.17	805.54	23.34 J	21.67 J	21.74 J
C1-Naphthalenes	33.54 U	33.54 U	33.54 U	11.51 J	7.25 J	7.83 J
C2-Naphthalenes	33.54 U	33.54 U	33.54 U	159.72 U	145.83 U	145.83 U
C3-Naphthalenes	33.54 U	33.54 U	33.54 U	159.72 U	145.83 U	145.83 U
C4-Naphthalenes	33.54 U	33.54 U	33.54 U	159.72 U	145.83 U	145.83 U
2-Methylnaphthalene	0.99 U	743.98	750.17	5.79 J	5.15 J	4.13 J
1-Methylnaphthalene	1.03 U	747.42	835.10	5.87 J	2.39 J	2.83 J
2,6-Dimethylnaphthalene	0.95 U	784.07	820.98	4.52 U	4.12 U	4.12 U
2,3,5-Trimethylnaphthalene	1.00 U	751.35	750.90	4.75 U	4.33 U	4.33 U
Biphenyl	0.83 U	775.66	841.78	3.97 U	3.62 U	3.62 U
Acenaphthylene	0.83 U	757.50	783.47	3.94 U	3.59 U	3.59 U
Acenaphthene	1.07 U	778.19	861.17	15.32 J	10.00 J	6.60 J
Fluorene	0.98 U	786.57	846.32	4.67 U	4.26 U	4.26 U
C1-Fluorenes	0.98 U	0.98 U	0.98 U	4.67 U	4.26 U	4.26 U
C2-Fluorenes	0.98 U	0.98 U	0.98 U	4.67 U	4.26 U	4.26 U
C3-Fluorenes	0.98 U	0.98 U	0.98 U	4.67 U	4.26 U	4.26 U
Phenanthrene	0.75 U	792.21	869.26	5.40 J	2.90 J	2.25 J
Anthracene	0.70 U	702.41	594.39	3.32 U	3.03 U	3.03 U
C1-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U	3.57 U	3.26 U	3.26 U
C2-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U	3.57 U	3.26 U	3.26 U
C3-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U	3.57 U	3.26 U	3.26 U
C4-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U	3.57 U	3.26 U	3.26 U
1-Methylphenanthrene	0.87 U	779.41	853.25	4.12 U	3.76 U	3.76 U
Dibenzothiophene	0.93 U	9.29 J	4.32 J	4.41 U	4.03 U	4.03 U
C1-Dibenzothiophenes	0.93 U	0.93 U	0.93 U	4.41 U	4.03 U	4.03 U
C2-Dibenzothiophenes	0.93 U	0.93 U	0.93 U	4.41 U	4.03 U	4.03 U
C3-Dibenzothiophenes	0.93 U	0.93 U	0.93 U	4.41 U	4.03 U	4.03 U
Fluoranthene	0.88 U	829.85	888.94	19.53 J	13.92 J	12.32 J
Pyrene	0.96 U	820.20	878.98	40.80 J	84.22	65.88 J
C1-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U	4.19 U	24.50 J	20.08 J
C2-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U	4.19 U	3.83 U	3.83 U
C3-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U	4.19 U	3.83 U	3.83 U
Benzo(a)anthracene	1.39 U	739.26	670.20	6.61 U	6.04 U	6.04 U
Chrysene	0.73 U	829.08	885.46	3.48 U	3.18 U	3.18 U
C1-Chrysenes	0.73 U	0.73 U	0.73 U	3.48 U	3.18 U	3.18 U
C2-Chrysenes	0.73 U	0.73 U	0.73 U	3.48 U	3.18 U	3.18 U
C3-Chrysenes	0.73 U	0.73 U	0.73 U	3.48 U	3.18 U	3.18 U
C4-Chrysenes	0.73 U	0.73 U	0.73 U	3.48 U	3.18 U	3.18 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W02-739MSvalues.xls



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Lab Control Sample Bay Water Spilked with FW21	SLC-BFSD2-F1-PAHs	SLC-BFSD2-F2-PAHs	SLC-BFSD2-F3-PAHs	
Battelle Sample ID	AB704PB	AB705LCS	AB705SRM	U2104	U2105	U2106
Battelle Batch ID	02-739	02-739	02-739	02-739	02-739	02-739
Data File	A1112.D	A1113.D	A1114.D	A1115.D	A1116.D	A1117.D
Extraction Date	12/20/02	12/20/02	12/20/02	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	0.21 L	0.23 L	0.23 L
Dilution Factor	1.667	1.667	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	16.67	16.67	79.38	72.48	72.48
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	0.86 U	732.95	785.29	4.09 U	3.73 U	3.73 U
Benzo(k)fluoranthene	0.87 U	876.31	910.53	4.13 U	3.77 U	3.77 U
Benzo(e)pyrene	0.91 U	822.90	924.70	4.32 U	3.94 U	3.94 U
Benzo(a)pyrene	1.30 U	764.42	745.92	6.18 U	5.65 U	5.65 U
Perylene	1.40 U	720.03	604.75	6.65 U	6.07 U	6.07 U
Indeno(1,2,3-c,d)pyrene	1.83 U	654.61	564.01	8.69 U	7.94 U	7.94 U
Dibenz(a,h)anthracene	2.09 U	722.63	549.23	9.93 U	9.07 U	9.07 U
Benzo(g,h,i)perylene	1.13 U	630.54	586.22	5.38 U	4.91 U	4.91 U
Naphthalene-d8	72	80	77	53	61	57
Phenanthrene-d10	69	74	75	66	69	66
Chrysene-d12	79	85	85	75	80	76

U = Analyte not detected, the sample specific Method Detection Limit (MDL) reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLC-BFSD2-F4-PAHs	SLC-BFSD2-F5-PAHs	SLC-BFSD2-F6-PAHs
Battelle Sample ID	U2107	U2108	U2109
Battelle Batch ID	02-739	02-739	02-739
Data File	A1118.D	A1120.D	A1121.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.23 L	0.225 L	0.23 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	72.48	74.09	72.48
Amount Units	ng/L	ng/L	ng/L
Naphthalene	24.86 J	21.63 J	22.90 J
C1-Naphthalenes	5.87 J	7.26 J	7.83 J
C2-Naphthalenes	145.83 U	149.07 U	145.83 U
C3-Naphthalenes	145.83 U	149.07 U	145.83 U
C4-Naphthalenes	145.83 U	149.07 U	145.83 U
2-Methylnaphthalene	4.35 J	6.08 J	6.67 J
1-Methylnaphthalene	3.33 J	3.93 J	3.48 J
2,6-Dimethylnaphthalene	4.12 U	4.22 U	4.12 U
2,3,5-Trimethylnaphthalene	4.33 U	4.43 U	4.33 U
Biphenyl	3.62 U	3.70 U	4.35 J
Acenaphthylene	3.59 U	3.67 U	3.59 U
Acenaphthene	6.38 J	2.67 J	4.65 U
Fluorene	4.26 U	4.36 U	4.26 U
C1-Fluorenes	4.26 U	4.36 U	4.26 U
C2-Fluorenes	4.26 U	4.36 U	4.26 U
C3-Fluorenes	4.26 U	4.36 U	4.26 U
Phenanthrene	3.26 U	11.63 J	3.41 J
Anthracene	3.03 U	3.10 U	3.03 U
C1-Phenanthrenes/Anthracenes	3.26 U	16.82 J	3.26 U
C2-Phenanthrenes/Anthracenes	3.26 U	14.97 J	3.26 U
C3-Phenanthrenes/Anthracenes	3.26 U	15.34 J	3.26 U
C4-Phenanthrenes/Anthracenes	3.26 U	3.33 U	3.26 U
1-Methylphenanthrene	3.76 U	4.59 J	3.76 U
Dibenzothiophene	4.03 U	3.41 J	4.03 U
C1-Dibenzothiophenes	4.03 U	6.74 J	4.03 U
C2-Dibenzothiophenes	4.03 U	18.74 J	4.03 U
C3-Dibenzothiophenes	4.03 U	16.74 J	4.03 U
Fluoranthene	10.65 J	24.08 J	10.00 J
Pyrene	82.70	130.92	72.62
C1-Fluoranthenes/Pyrenes	26.02 J	46.75 J	14.57 J
C2-Fluoranthenes/Pyrenes	3.83 U	30.67 J	3.83 U
C3-Fluoranthenes/Pyrenes	3.83 U	20.97 J	3.83 U
Benzo(a)anthracene	6.04 U	2.96 J	6.04 U
Chrysene	3.18 U	15.41 J	3.18 U
C1-Chrysenes	3.18 U	17.26 J	3.18 U
C2-Chrysenes	3.18 U	3.25 U	3.18 U
C3-Chrysenes	3.18 U	3.25 U	3.18 U
C4-Chrysenes	3.18 U	3.25 U	3.18 U



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	SLC-BFSD2-F4-PAHs	SLC-BFSD2-F5-PAHs	SLC-BFSD2-F6-PAHs
Battelle Sample ID	U2107	U2108	U2109
Battelle Batch ID	02-739	02-739	02-739
Data File	A1118.D	A1120.D	A1121.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.23 L	0.225 L	0.23 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	72.48	74.09	72.48
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	3.73 U	52.38 J	3.73 U
Benzo(k)fluoranthene	3.77 U	54.97 J	3.77 U
Benzo(e)pyrene	3.94 U	51.64 J	3.94 U
Benzo(a)pyrene	5.65 U	58.46 J	5.65 U
Perylene	6.07 U	13.78 J	6.07 U
Indeno(1,2,3-c,d)pyrene	7.94 U	10.22 J	7.94 U
Dibenz(a,h)anthracene	9.07 U	9.27 U	9.07 U
Benzo(g,h,i)perylene	4.91 U	12.37 J	4.91 U
Naphthalene-d8	63	57	61
Phenanthrene-d10	68	70	68
Chrysene-d12	75	79	77

U = Analyte not detected, the sample specific Mett  
J = Analyte detected below the sample specific Re  
NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-BFSD1-A1-PAHs	BPC-BFSD1-A2-PAHs	BPC-BFSD1-A3-PAHs
Battelle Sample ID	U2110	U2111	U2112
Battelle Batch ID	02-739	02-739	02-739
Data File	A1122.D	A1123.D	A1124.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.22 L	0.21 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	75.77	79.38
Amount Units	ng/L	ng/L	ng/L
Naphthalene	25.48 J	22.13 J	27.23 J
C1-Naphthalenes	7.14 J	6.74 J	8.41 J
C2-Naphthalenes	159.72 U	152.46 U	159.72 U
C3-Naphthalenes	159.72 U	152.46 U	159.72 U
C4-Naphthalenes	159.72 U	152.46 U	159.72 U
2-Methylnaphthalene	5.00 J	4.39 J	5.40 J
1-Methylnaphthalene	6.03 J	4.47 J	4.92 J
2,6-Dimethylnaphthalene	4.52 U	4.31 U	4.52 U
2,3,5-Trimethylnaphthalene	4.75 U	4.53 U	4.75 U
Biphenyl	3.97 U	3.79 U	3.97 U
Acenaphthylene	3.02 J	2.35 J	3.94 U
Acenaphthene	26.75 J	35.61 J	27.47 J
Fluorene	4.67 U	4.46 U	4.67 U
C1-Fluorenes	4.67 U	4.46 U	4.67 U
C2-Fluorenes	4.67 U	4.46 U	4.67 U
C3-Fluorenes	4.67 U	4.46 U	4.67 U
Phenanthrene	1.75 J	3.41 U	2.78 J
Anthracene	3.32 U	3.17 U	3.32 U
C1-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.57 U
C2-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.57 U
C3-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.57 U
C4-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.57 U
1-Methylphenanthrene	4.12 U	3.93 U	4.12 U
Dibenzothiophene	3.81 J	2.88 J	3.89 J
C1-Dibenzothiophenes	4.41 U	4.21 U	4.41 U
C2-Dibenzothiophenes	4.41 U	4.21 U	4.41 U
C3-Dibenzothiophenes	4.41 U	4.21 U	4.41 U
Fluoranthene	37.23 J	52.43 J	39.69 J
Pyrene	7.14 J	6.44 J	4.92 J
C1-Fluoranthenes/Pyrenes	4.19 U	15.00 J	4.19 U
C2-Fluoranthenes/Pyrenes	4.19 U	4.00 U	4.19 U
C3-Fluoranthenes/Pyrenes	4.19 U	4.00 U	4.19 U
Benzo(a)anthracene	6.61 U	6.31 U	6.61 U
Chrysene	3.48 U	3.33 U	3.48 U
C1-Chrysenes	3.48 U	3.33 U	3.48 U
C2-Chrysenes	3.48 U	3.33 U	3.48 U
C3-Chrysenes	3.48 U	3.33 U	3.48 U
C4-Chrysenes	3.48 U	3.33 U	3.48 U



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-BFSD1-A1-PAHs	BPC-BFSD1-A2-PAHs	BPC-BFSD1-A3-PAHs
Battelle Sample ID	U2110	U2111	U2112
Battelle Batch ID	02-739	02-739	02-739
Data File	A1122.D	A1123.D	A1124.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/19/03	01/19/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.22 L	0.21 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	75.77	79.38
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	4.09 U	3.90 U	4.09 U
Benzo(k)fluoranthene	4.13 U	3.94 U	4.13 U
Benzo(e)pyrene	4.32 U	4.12 U	4.32 U
Benzo(a)pyrene	6.18 U	5.90 U	6.18 U
Perylene	6.65 U	6.35 U	6.65 U
Indeno(1,2,3-c,d)pyrene	8.69 U	8.30 U	8.69 U
Dibenz(a,h)anthracene	9.93 U	9.48 U	9.93 U
Benzo(g,h,i)perylene	5.38 U	5.14 U	5.38 U
Naphthalene-d8	64	60	62
Phenanthrene-d10	72	64	67
Chrysene-d12	80	76	75

U = Analyte not detected, the sample specific Mett  
J = Analyte detected below the sample specific Re  
NA = Not applicable.  
N = QC value outside the accuracy or precision da





Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-BFSD1-A4-PAHs	BPC-BFSD1-A5-PAHs	BPC-SMA2-Comp13-PAHs
Battelle Sample ID	U2113	U2114	U2115
Battelle Batch ID	02-739	02-739	02-739
Data File	A1125.D	A1126.D	A1177.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/20/03	01/21/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.2 L	0.225 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	83.35	74.09
Amount Units	ng/L	ng/L	ng/L
Naphthalene	19.61 J	23.75 J	31.71 J
C1-Naphthalenes	8.73 J	167.71 U	12.37 J
C2-Naphthalenes	159.72 U	167.71 U	149.07 U
C3-Naphthalenes	159.72 U	167.71 U	149.07 U
C4-Naphthalenes	159.72 U	167.71 U	149.07 U
2-Methylnaphthalene	4.13 J	4.95 U	9.48 J
1-Methylnaphthalene	4.13 J	5.13 U	7.78 J
2,6-Dimethylnaphthalene	4.52 U	4.74 U	4.22 U
2,3,5-Trimethylnaphthalene	4.75 U	4.98 U	4.43 U
Biphenyl	3.97 U	4.17 U	6.67 J
Acenaphthylene	3.94 U	4.13 U	3.67 U
Acenaphthene	25.08 J	22.92 J	7.33 J
Fluorene	4.67 U	5.75 J	4.36 U
C1-Fluorenes	4.67 U	4.90 U	4.36 U
C2-Fluorenes	4.67 U	4.90 U	4.36 U
C3-Fluorenes	4.67 U	4.90 U	4.36 U
Phenanthrene	3.57 U	10.42 J	5.11 J
Anthracene	3.32 U	3.48 U	3.10 U
C1-Phenanthrenes/Anthracenes	3.57 U	3.75 U	3.33 U
C2-Phenanthrenes/Anthracenes	3.57 U	3.75 U	3.33 U
C3-Phenanthrenes/Anthracenes	3.57 U	3.75 U	3.33 U
C4-Phenanthrenes/Anthracenes	3.57 U	3.75 U	3.33 U
1-Methylphenanthrene	4.12 U	4.33 U	3.85 U
Dibenzothiophene	3.18 J	3.58 J	14.00 J
C1-Dibenzothiophenes	4.41 U	4.63 U	4.12 U
C2-Dibenzothiophenes	4.41 U	4.63 U	4.12 U
C3-Dibenzothiophenes	4.41 U	4.63 U	4.12 U
Fluoranthene	35.56 J	32.34 J	5.78 J
Pyrene	14.61 J	19.92 J	3.78 J
C1-Fluoranthenes/Pyrenes	14.69 J	4.40 U	3.91 U
C2-Fluoranthenes/Pyrenes	4.19 U	4.40 U	3.91 U
C3-Fluoranthenes/Pyrenes	4.19 U	4.40 U	3.91 U
Benzo(a)anthracene	6.61 U	6.94 U	6.17 U
Chrysene	3.48 U	3.66 U	3.25 U
C1-Chrysenes	3.48 U	3.66 U	3.25 U
C2-Chrysenes	3.48 U	3.66 U	3.25 U
C3-Chrysenes	3.48 U	3.66 U	3.25 U
C4-Chrysenes	3.48 U	3.66 U	3.25 U



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-BFSD1-A4-PAHs	BPC-BFSD1-A5-PAHs	BPC-SMA2-Comp13-PAHs
Battelle Sample ID	U2113	U2114	U2115
Battelle Batch ID	02-739	02-739	02-739
Data File	A1125.D	A1126.D	A1177.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/19/03	01/20/03	01/21/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.2 L	0.225 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	83.35	74.09
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	4.09 U	4.29 U	3.82 U
Benzo(k)fluoranthene	4.13 U	4.33 U	3.85 U
Benzo(e)pyrene	4.32 U	4.53 U	4.03 U
Benzo(a)pyrene	6.18 U	6.49 U	5.77 U
Perylene	6.65 U	6.98 U	6.21 U
Indeno(1,2,3-c,d)pyrene	8.69 U	9.13 U	8.11 U
Dibenz(a,h)anthracene	9.93 U	10.43 U	9.27 U
Benzo(g,h,i)perylene	5.38 U	5.65 U	5.02 U
Naphthalene-d8	63	66	49
Phenanthrene-d10	67	67	58
Chrysene-d12	73	75	64

U = Analyte not detected, the sample specific Mett  
J = Analyte detected below the sample specific Re  
NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-SMA2-4-PAHs	BPC-SMA2-Comp56-PAHs	Duxbury Water
Battelle Sample ID	U2116	U2117	U2211
Battelle Batch ID	02-739	02-739	02-739
Data File	A1178.D	A1179.D	A1180.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/22/03	01/22/03	01/22/03
Matrix	Water	Water	Water
Sample Size	0.23 L	0.225 L	1 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	72.48	74.09	16.67
Amount Units	ng/L	ng/L	ng/L
Naphthalene	31.60 J	24.15 J	14.24 J
C1-Naphthalenes	12.83 J	11.63 J	7.67 J
C2-Naphthalenes	145.83 U	149.07 U	33.54 U
C3-Naphthalenes	145.83 U	149.07 U	33.54 U
C4-Naphthalenes	145.83 U	149.07 U	33.54 U
2-Methylnaphthalene	10.07 J	7.93 J	6.83 J
1-Methylnaphthalene	7.47 J	6.22 J	4.50 J
2,6-Dimethylnaphthalene	4.12 U	4.22 U	0.95 U
2,3,5-Trimethylnaphthalene	4.33 U	4.43 U	1.00 U
Biphenyl	6.74 J	5.63 J	1.75 J
Acenaphthylene	2.32 J	3.67 U	0.82 J
Acenaphthene	27.32 J	18.97 J	1.05 J
Fluorene	4.26 U	4.36 U	1.47 J
C1-Fluorenes	4.26 U	4.36 U	0.98 U
C2-Fluorenes	4.26 U	4.36 U	0.98 U
C3-Fluorenes	4.26 U	4.36 U	0.98 U
Phenanthrene	3.26 U	3.33 U	5.72 J
Anthracene	3.03 U	3.10 U	0.70 U
C1-Phenanthrenes/Anthracenes	3.26 U	3.33 U	0.75 U
C2-Phenanthrenes/Anthracenes	3.26 U	3.33 U	0.75 U
C3-Phenanthrenes/Anthracenes	3.26 U	3.33 U	0.75 U
C4-Phenanthrenes/Anthracenes	3.26 U	3.33 U	0.75 U
1-Methylphenanthrene	3.76 U	3.85 U	0.87 U
Dibenzothiophene	4.03 U	11.48 J	2.50 J
C1-Dibenzothiophenes	4.03 U	4.12 U	0.93 U
C2-Dibenzothiophenes	4.03 U	4.12 U	0.93 U
C3-Dibenzothiophenes	4.03 U	4.12 U	0.93 U
Fluoranthene	10.80 J	9.04 J	5.62 J
Pyrene	4.16 U	4.25 U	4.95 J
C1-Fluoranthenes/Pyrenes	3.83 U	3.91 U	0.88 U
C2-Fluoranthenes/Pyrenes	3.83 U	3.91 U	0.88 U
C3-Fluoranthenes/Pyrenes	3.83 U	3.91 U	0.88 U
Benzo(a)anthracene	6.04 U	6.17 U	1.07 J
Chrysene	3.18 U	3.25 U	3.38 J
C1-Chrysenes	3.18 U	3.25 U	0.73 U
C2-Chrysenes	3.18 U	3.25 U	0.73 U
C3-Chrysenes	3.18 U	3.25 U	0.73 U
C4-Chrysenes	3.18 U	3.25 U	0.73 U



Project Name SPAWAR TO0009 -  
Project Number G600112

Client Sample ID	BPC-SMA2-4-PAHs	BPC-SMA2-Comp56-PAHs	Duxbury Water
Battelle Sample ID	U2116	U2117	U2211
Battelle Batch ID	02-739	02-739	02-739
Data File	A1178.D	A1179.D	A1180.D
Extraction Date	12/20/02	12/20/02	12/20/02
Acquired Date	01/22/03	01/22/03	01/22/03
Matrix	Water	Water	Water
Sample Size	0.23 L	0.225 L	1 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	72.48	74.09	16.67
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	3.73 U	3.82 U	0.86 U
Benzo(k)fluoranthene	3.77 U	3.85 U	0.87 U
Benzo(e)pyrene	3.94 U	4.03 U	0.91 U
Benzo(a)pyrene	5.65 U	5.77 U	1.30 U
Perylene	6.07 U	6.21 U	1.40 U
Indeno(1,2,3-c,d)pyrene	7.94 U	8.11 U	1.83 U
Dibenz(a,h)anthracene	9.07 U	9.27 U	2.09 U
Benzo(g,h,i)perylene	4.91 U	5.02 U	1.98 J
Naphthalene-d8	56	53	55
Phenanthrene-d10	69	66	73
Chrysene-d12	76	74	80

U = Analyte not detected, the sample specific Mett  
J = Analyte detected below the sample specific Re  
NA = Not applicable.  
N = QC value outside the accuracy or precision da



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Lab Control Sample Bay Water Spilled with FW21	
Battelle Sample ID	AB729PB	AB730LCS	AB731SRM
Battelle Batch ID	02-745	02-745	02-745
Data File	A1290.D	A1291.D	A1292.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/25/03	01/26/03	01/26/03
Matrix	Water	Water	Water
Sample Size	1 L	1 L	1 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	16.67	16.67
Amount Units	ng/L	ng/L	ng/L
Naphthalene	5.17 J	691.29	561.96
C1-Naphthalenes	1.00 J	33.54 U	33.54 U
C2-Naphthalenes	33.54 U	33.54 U	33.54 U
C3-Naphthalenes	33.54 U	33.54 U	33.54 U
C4-Naphthalenes	33.54 U	33.54 U	33.54 U
2-Methylnaphthalene	0.82 J	687.59	542.76
1-Methylnaphthalene	0.65 J	689.67	611.74
2,6-Dimethylnaphthalene	0.95 U	729.58	631.54
2,3,5-Trimethylnaphthalene	1.00 U	732.85	625.59
Biphenyl	0.55 J	708.31	633.63
Acenaphthylene	0.83 U	734.10	634.86
Acenaphthene	1.07 U	747.98	697.22
Fluorene	0.98 U	778.37	742.82
C1-Fluorenes	0.98 U	0.98 U	0.98 U
C2-Fluorenes	0.98 U	0.98 U	0.98 U
C3-Fluorenes	0.98 U	0.98 U	0.98 U
Phenanthrene	0.75 U	808.36	892.70
Anthracene	0.70 U	655.41	563.30
C1-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U
C2-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U
C3-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U
C4-Phenanthrenes/Anthracenes	0.75 U	0.75 U	0.75 U
1-Methylphenanthrene	0.87 U	791.84	840.57
Dibenzothiophene	0.93 U	8.30 J	5.87 J
C1-Dibenzothiophenes	0.93 U	0.93 U	0.93 U
C2-Dibenzothiophenes	0.93 U	0.93 U	0.93 U
C3-Dibenzothiophenes	0.93 U	0.93 U	0.93 U
Fluoranthene	0.88 U	903.91	1062.40
Pyrene	0.96 U	896.98	1023.12
C1-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U
C2-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U
C3-Fluoranthenes/Pyrenes	0.88 U	0.88 U	0.88 U
Benzo(a)anthracene	1.39 U	767.39	712.23
Chrysene	0.73 U	950.14	1009.77
C1-Chrysenes	0.73 U	0.73 U	0.73 U
C2-Chrysenes	0.73 U	0.73 U	0.73 U
C3-Chrysenes	0.73 U	0.73 U	0.73 U
C4-Chrysenes	0.73 U	0.73 U	0.73 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W02-745MSvalues.xls



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
 Project Number G600112

Client Sample ID	Procedural Blank	Lab Control Sample Bay Water Spilled with FW21	
Battelle Sample ID	AB729PB	AB730LCS	AB731SRM
Battelle Batch ID	02-745	02-745	02-745
Data File	A1290.D	A1291.D	A1292.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/25/03	01/26/03	01/26/03
Matrix	Water	Water	Water
Sample Size	1 L	1 L	1 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	16.67	16.67	16.67
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	0.86 U	979.11	953.92
Benzo(k)fluoranthene	0.87 U	967.84	1035.86
Benzo(e)pyrene	0.91 U	849.55	930.69
Benzo(a)pyrene	1.30 U	757.15	754.27
Perylene	1.40 U	699.04	618.06
Indeno(1,2,3-c,d)pyrene	1.83 U	458.31	397.46
Dibenz(a,h)anthracene	2.09 U	654.11	485.06
Benzo(g,h,i)perylene	1.13 U	553.56	491.48
Naphthalene-d8	79	83	64
Phenanthrene-d10	77	75	73
Chrysene-d12	86	94	91

U = Analyte not detected, the sample specific Method Detection Limit (MDL) reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLA-BFSD2-F7-PAHs	SLA-BFSD2-F8-PAHs	SLA-BFSD2-F9-PAHs
Battelle Sample ID	U2213	U2214	U2215
Battelle Batch ID	02-745	02-745	02-745
Data File	A1293.D	A1294.D	A1295.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/26/03	01/26/03	01/26/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.22 L	0.22 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	75.77	75.77
Amount Units	ng/L	ng/L	ng/L
Naphthalene	30.80 J	19.25 J	24.55 J
C1-Naphthalenes	15.72 J	4.93 J	6.67 J
C2-Naphthalenes	159.72 U	152.46 U	152.46 U
C3-Naphthalenes	159.72 U	152.46 U	152.46 U
C4-Naphthalenes	159.72 U	152.46 U	152.46 U
2-Methylnaphthalene	11.11 J	4.32 J	5.76 J
1-Methylnaphthalene	11.99 J	4.62 J	4.17 J
2,6-Dimethylnaphthalene	4.52 U	4.31 U	4.31 U
2,3,5-Trimethylnaphthalene	4.75 U	4.53 U	4.53 U
Biphenyl	7.06 J	3.79 U	3.79 U
Acenaphthylene	3.18 J	3.76 U	3.76 U
Acenaphthene	25.56 J	13.26 J	12.35 J
Fluorene	10.88 J	3.71 J	4.46 U
C1-Fluorenes	4.67 U	4.46 U	4.46 U
C2-Fluorenes	4.67 U	4.46 U	4.46 U
C3-Fluorenes	4.67 U	4.46 U	4.46 U
Phenanthrene	16.91 J	6.36 J	5.91 J
Anthracene	3.18 J	3.79 J	3.17 U
C1-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.41 U
C2-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.41 U
C3-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.41 U
C4-Phenanthrenes/Anthracenes	3.57 U	3.41 U	3.41 U
1-Methylphenanthrene	4.12 U	3.93 U	3.93 U
Dibenzothiophene	4.41 U	4.21 U	4.21 U
C1-Dibenzothiophenes	4.41 U	4.21 U	4.21 U
C2-Dibenzothiophenes	4.41 U	4.21 U	4.21 U
C3-Dibenzothiophenes	4.41 U	4.21 U	4.21 U
Fluoranthene	30.24 J	12.05 J	13.56 J
Pyrene	34.69 J	45.99 J	45.31 J
C1-Fluoranthenes/Pyrenes	4.19 U	23.64 J	4.00 U
C2-Fluoranthenes/Pyrenes	4.19 U	4.00 U	4.00 U
C3-Fluoranthenes/Pyrenes	4.19 U	4.00 U	4.00 U
Benzo(a)anthracene	6.61 U	6.31 U	6.31 U
Chrysene	3.48 U	12.81 J	3.33 U
C1-Chrysenes	3.48 U	3.33 U	3.33 U
C2-Chrysenes	3.48 U	3.33 U	3.33 U
C3-Chrysenes	3.48 U	3.33 U	3.33 U
C4-Chrysenes	3.48 U	3.33 U	3.33 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W02-745MSvalues.xls



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLA-BFSD2-F7-PAHs	SLA-BFSD2-F8-PAHs	SLA-BFSD2-F9-PAHs
Battelle Sample ID	U2213	U2214	U2215
Battelle Batch ID	02-745	02-745	02-745
Data File	A1293.D	A1294.D	A1295.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/26/03	01/26/03	01/26/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.22 L	0.22 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	75.77	75.77
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	4.09 U	10.91 J	3.90 U
Benzo(k)fluoranthene	4.13 U	15.00 J	3.94 U
Benzo(e)pyrene	4.32 U	4.12 U	4.12 U
Benzo(a)pyrene	6.18 U	5.90 U	5.90 U
Perylene	6.65 U	6.35 U	6.35 U
Indeno(1,2,3-c,d)pyrene	8.69 U	8.30 U	8.30 U
Dibenz(a,h)anthracene	9.93 U	9.48 U	9.48 U
Benzo(g,h,i)perylene	5.38 U	5.14 U	5.14 U
Naphthalene-d8	61	51	63
Phenanthrene-d10	72	66	74
Chrysene-d12	80	83	90

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p





Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLA-BFSD2-F10-PAHs	SLA-BFSD2-F11-PAHs	SLB-BFSD1-A6-PAHs
Battelle Sample ID	U2216	U2217	U2218
Battelle Batch ID	02-745	02-745	02-745
Data File	A1296.D	A1297.D	A1755.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/26/03	01/26/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.225 L	0.225 L	0.2 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	74.09	74.09	83.35
Amount Units	ng/L	ng/L	ng/L
Naphthalene	21.04 J	20.89 J	25.92 J
C1-Naphthalenes	6.00 J	149.07 U	12.67 J
C2-Naphthalenes	149.07 U	149.07 U	167.71 U
C3-Naphthalenes	149.07 U	149.07 U	167.71 U
C4-Naphthalenes	149.07 U	149.07 U	167.71 U
2-Methylnaphthalene	5.26 J	4.40 U	10.00 J
1-Methylnaphthalene	3.11 J	4.56 U	7.50 J
2,6-Dimethylnaphthalene	4.22 U	4.22 U	4.74 U
2,3,5-Trimethylnaphthalene	4.43 U	4.43 U	4.98 U
Biphenyl	3.70 U	3.70 U	3.58 J
Acenaphthylene	3.67 U	3.67 U	3.08 J
Acenaphthene	10.67 J	8.15 J	6.92 J
Fluorene	4.36 U	4.36 U	4.90 U
C1-Fluorenes	4.36 U	4.36 U	4.90 U
C2-Fluorenes	4.36 U	4.36 U	4.90 U
C3-Fluorenes	4.36 U	4.36 U	4.90 U
Phenanthrene	8.15 J	4.15 J	5.58 J
Anthracene	3.93 J	3.10 U	3.48 U
C1-Phenanthrenes/Anthracenes	3.33 U	3.33 U	3.75 U
C2-Phenanthrenes/Anthracenes	3.33 U	3.33 U	3.75 U
C3-Phenanthrenes/Anthracenes	3.33 U	3.33 U	3.75 U
C4-Phenanthrenes/Anthracenes	3.33 U	3.33 U	3.75 U
1-Methylphenanthrene	3.85 U	3.85 U	4.33 U
Dibenzothiophene	4.12 U	4.12 U	5.00 J
C1-Dibenzothiophenes	4.12 U	4.12 U	4.63 U
C2-Dibenzothiophenes	4.12 U	4.12 U	4.63 U
C3-Dibenzothiophenes	4.12 U	4.12 U	4.63 U
Fluoranthene	11.48 J	12.30 J	16.59 J
Pyrene	65.72 J	64.09 J	15.50 J
C1-Fluoranthenes/Pyrenes	15.86 J	29.78 J	36.26 J
C2-Fluoranthenes/Pyrenes	3.91 U	3.91 U	34.59 J
C3-Fluoranthenes/Pyrenes	3.91 U	3.91 U	29.34 J
Benzo(a)anthracene	6.17 U	6.17 U	5.67 J
Chrysene	3.25 U	3.25 U	15.09 J
C1-Chrysenes	3.25 U	3.25 U	3.66 U
C2-Chrysenes	3.25 U	3.25 U	3.66 U
C3-Chrysenes	3.25 U	3.25 U	3.66 U
C4-Chrysenes	3.25 U	3.25 U	3.66 U



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLA-BFSD2-F10-PAHs	SLA-BFSD2-F11-PAHs	SLB-BFSD1-A6-PAHs
Battelle Sample ID	U2216	U2217	U2218
Battelle Batch ID	02-745	02-745	02-745
Data File	A1296.D	A1297.D	A1755.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	01/26/03	01/26/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.225 L	0.225 L	0.2 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	74.09	74.09	83.35
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	3.82 U	24.23 J	79.35 J
Benzo(k)fluoranthene	3.85 U	30.45 J	69.68 J
Benzo(e)pyrene	4.03 U	17.56 J	43.93 J
Benzo(a)pyrene	5.77 U	29.64 J	65.18 J
Perylene	6.21 U	6.21 U	14.09 J
Indeno(1,2,3-c,d)pyrene	8.11 U	8.11 U	31.92 J
Dibenz(a,h)anthracene	9.27 U	9.27 U	10.43 U
Benzo(g,h,i)perylene	5.02 U	5.02 U	23.42 J
Naphthalene-d8	53	60	63
Phenanthrene-d10	67	71	74
Chrysene-d12	79	86	80

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLB-BFSD1-A7-PAHs	SLB-BFSD1-A8-PAHs	SLB-BFSD1-A9-PAHs
Battelle Sample ID	U2219	U2220	U2221
Battelle Batch ID	02-745	02-745	02-745
Data File	A1756.D	A1757.D	A1758.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.17 L	0.22 L	0.215 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	98.06	75.77	77.53
Amount Units	ng/L	ng/L	ng/L
Naphthalene	32.85 J	22.88 J	28.61 J
C1-Naphthalenes	6.28 J	8.11 J	11.24 J
C2-Naphthalenes	197.30 U	152.46 U	156.01 U
C3-Naphthalenes	197.30 U	152.46 U	156.01 U
C4-Naphthalenes	197.30 U	152.46 U	156.01 U
2-Methylnaphthalene	5.20 J	5.83 J	7.99 J
1-Methylnaphthalene	4.02 J	3.33 J	4.81 J
2,6-Dimethylnaphthalene	5.58 U	4.31 U	4.41 U
2,3,5-Trimethylnaphthalene	5.86 U	4.53 U	4.64 U
Biphenyl	4.12 J	2.80 J	3.95 J
Acenaphthylene	4.86 U	1.67 J	3.85 U
Acenaphthene	6.30 U	5.23 J	4.98 U
Fluorene	5.77 U	4.46 U	4.56 U
C1-Fluorenes	5.77 U	4.46 U	4.56 U
C2-Fluorenes	5.77 U	4.46 U	4.56 U
C3-Fluorenes	5.77 U	4.46 U	4.56 U
Phenanthrene	4.31 J	2.73 J	3.02 J
Anthracene	4.10 U	3.17 U	3.24 U
C1-Phenanthrenes/Anthracenes	4.41 U	3.41 U	3.49 U
C2-Phenanthrenes/Anthracenes	4.41 U	3.41 U	3.49 U
C3-Phenanthrenes/Anthracenes	4.41 U	3.41 U	3.49 U
C4-Phenanthrenes/Anthracenes	4.41 U	3.41 U	3.49 U
1-Methylphenanthrene	5.09 U	3.93 U	4.02 U
Dibenzothiophene	5.45 U	2.96 J	4.31 U
C1-Dibenzothiophenes	5.45 U	4.21 U	4.31 U
C2-Dibenzothiophenes	5.45 U	4.21 U	4.31 U
C3-Dibenzothiophenes	5.45 U	4.21 U	4.31 U
Fluoranthene	4.71 J	5.99 J	4.65 J
Pyrene	3.33 J	2.80 J	4.45 U
C1-Fluoranthenes/Pyrenes	5.18 U	15.00 J	12.48 J
C2-Fluoranthenes/Pyrenes	5.18 U	4.00 U	4.09 U
C3-Fluoranthenes/Pyrenes	5.18 U	4.00 U	4.09 U
Benzo(a)anthracene	8.17 U	6.31 U	6.46 U
Chrysene	4.30 U	3.33 U	3.40 U
C1-Chrysenes	4.30 U	3.33 U	3.40 U
C2-Chrysenes	4.30 U	3.33 U	3.40 U
C3-Chrysenes	4.30 U	3.33 U	3.40 U
C4-Chrysenes	4.30 U	3.33 U	3.40 U



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLB-BFSD1-A7-PAHs	SLB-BFSD1-A8-PAHs	SLB-BFSD1-A9-PAHs
Battelle Sample ID	U2219	U2220	U2221
Battelle Batch ID	02-745	02-745	02-745
Data File	A1756.D	A1757.D	A1758.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.17 L	0.22 L	0.215 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	98.06	75.77	77.53
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	5.05 U	20.69 J	3.99 U
Benzo(k)fluoranthene	5.10 U	15.76 J	4.03 U
Benzo(e)pyrene	5.33 U	11.67 J	4.22 U
Benzo(a)pyrene	7.64 U	18.72 J	6.04 U
Perylene	8.22 U	6.35 U	6.50 U
Indeno(1,2,3-c,d)pyrene	10.74 U	7.43 J	8.49 U
Dibenz(a,h)anthracene	12.27 U	9.48 U	9.70 U
Benzo(g,h,i)perylene	6.65 U	3.26 J	5.26 U
Naphthalene-d8	61	62	70
Phenanthrene-d10	73	72	77
Chrysene-d12	82	77	82

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLB-BFSD1-A10-PAHs	SLA-SMA-1-PAHs	SLA-SMA-2-PAHs
Battelle Sample ID	U2222	U2223	U2224
Battelle Batch ID	02-745	02-745	02-745
Data File	A1760A.D	A1760.D	A1761.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.245 L	0.21 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	68.04	79.38
Amount Units	ng/L	ng/L	ng/L
Naphthalene	27.39 J	22.25 J	22.07 J
C1-Naphthalenes	11.11 J	8.85 J	8.02 J
C2-Naphthalenes	159.72 U	136.90 U	159.72 U
C3-Naphthalenes	159.72 U	136.90 U	159.72 U
C4-Naphthalenes	159.72 U	136.90 U	159.72 U
2-Methylnaphthalene	6.43 J	5.85 J	5.95 J
1-Methylnaphthalene	5.40 J	4.22 J	4.52 J
2,6-Dimethylnaphthalene	4.52 U	3.87 U	4.52 U
2,3,5-Trimethylnaphthalene	4.75 U	4.07 U	4.75 U
Biphenyl	2.54 J	2.79 J	3.10 J
Acenaphthylene	2.38 J	3.37 U	3.94 U
Acenaphthene	5.10 U	4.37 U	5.10 U
Fluorene	4.67 U	4.00 U	4.67 U
C1-Fluorenes	4.67 U	4.00 U	4.67 U
C2-Fluorenes	4.67 U	4.00 U	4.67 U
C3-Fluorenes	4.67 U	4.00 U	4.67 U
Phenanthrene	3.73 J	2.79 J	4.29 J
Anthracene	3.32 U	1.91 J	3.32 U
C1-Phenanthrenes/Anthracenes	3.57 U	3.06 U	3.57 U
C2-Phenanthrenes/Anthracenes	3.57 U	3.06 U	3.57 U
C3-Phenanthrenes/Anthracenes	3.57 U	3.06 U	3.57 U
C4-Phenanthrenes/Anthracenes	3.57 U	3.06 U	3.57 U
1-Methylphenanthrene	4.12 U	3.53 U	4.12 U
Dibenzothiophene	4.41 U	3.78 U	4.41 U
C1-Dibenzothiophenes	4.41 U	3.78 U	4.41 U
C2-Dibenzothiophenes	4.41 U	3.78 U	4.41 U
C3-Dibenzothiophenes	4.41 U	3.78 U	4.41 U
Fluoranthene	3.18 J	2.79 J	4.21 J
Pyrene	1.67 J	2.93 J	4.92 J
C1-Fluoranthenes/Pyrenes	6.35 J	7.42 J	4.19 U
C2-Fluoranthenes/Pyrenes	4.19 U	3.59 U	4.19 U
C3-Fluoranthenes/Pyrenes	4.19 U	3.59 U	4.19 U
Benzo(a)anthracene	6.61 U	5.67 U	6.61 U
Chrysene	4.29 J	2.99 U	3.48 U
C1-Chrysenes	3.48 U	2.99 U	3.48 U
C2-Chrysenes	3.48 U	2.99 U	3.48 U
C3-Chrysenes	3.48 U	2.99 U	3.48 U
C4-Chrysenes	3.48 U	2.99 U	3.48 U



Project Name SPAWAI  
Project Number G60011

Client Sample ID	SLB-BFSD1-A10-PAHs	SLA-SMA-1-PAHs	SLA-SMA-2-PAHs
Battelle Sample ID	U2222	U2223	U2224
Battelle Batch ID	02-745	02-745	02-745
Data File	A1760A.D	A1760.D	A1761.D
Extraction Date	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water
Sample Size	0.21 L	0.245 L	0.21 L
Dilution Factor	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL
Min Reporting Limit	79.38	68.04	79.38
Amount Units	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	4.09 U	12.04 J	8.57 J
Benzo(k)fluoranthene	4.13 U	10.95 J	7.86 J
Benzo(e)pyrene	4.32 U	8.91 J	7.86 J
Benzo(a)pyrene	6.18 U	12.25 J	6.83 J
Perylene	6.65 U	5.70 U	6.65 U
Indeno(1,2,3-c,d)pyrene	8.69 U	6.26 J	5.87 J
Dibenz(a,h)anthracene	9.93 U	8.51 U	9.93 U
Benzo(g,h,i)perylene	5.38 U	4.61 U	5.38 U
Naphthalene-d8	72	69	65
Phenanthrene-d10	79	78	74
Chrysene-d12	82	83	82

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p



Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLA-SMA-3-PAHs	SLA-SMA-Comp45-PAHs	SLA-SMA-6-PAHs	SLB-SMB-2-PAHs
Battelle Sample ID	U2225	U2226	U2227	U2228
Battelle Batch ID	02-745	02-745	02-745	02-745
Data File	A1762.D	A1764.D	A1765.D	A1766.D
Extraction Date	12/26/02	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water	Water
Sample Size	0.22 L	0.22 L	0.25 L	0.215 L
Dilution Factor	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	75.77	75.77	66.68	77.53
Amount Units	ng/L	ng/L	ng/L	ng/L
Naphthalene	26.14 J	22.28 J	21.34 J	26.75 J
C1-Naphthalenes	9.55 J	10.31 J	7.00 J	8.22 J
C2-Naphthalenes	152.46 U	152.46 U	134.17 U	156.01 U
C3-Naphthalenes	152.46 U	152.46 U	134.17 U	156.01 U
C4-Naphthalenes	152.46 U	152.46 U	134.17 U	156.01 U
2-Methylnaphthalene	6.36 J	6.67 J	6.00 J	8.22 J
1-Methylnaphthalene	5.15 J	5.30 J	4.33 J	2.48 J
2,6-Dimethylnaphthalene	4.31 U	4.31 U	3.79 U	4.41 U
2,3,5-Trimethylnaphthalene	4.53 U	4.53 U	3.99 U	4.64 U
Biphenyl	4.24 J	3.11 J	2.67 J	4.50 J
Acenaphthylene	2.20 J	3.76 J	1.67 J	3.85 U
Acenaphthene	4.86 U	4.86 U	4.28 U	4.98 U
Fluorene	4.46 U	4.46 U	3.92 U	4.56 U
C1-Fluorenes	4.46 U	4.46 U	3.92 U	4.56 U
C2-Fluorenes	4.46 U	4.46 U	3.92 U	4.56 U
C3-Fluorenes	4.46 U	4.46 U	3.92 U	4.56 U
Phenanthrene	3.03 J	5.53 J	5.20 J	3.95 J
Anthracene	3.17 U	3.17 U	2.79 U	3.24 U
C1-Phenanthrenes/Anthracenes	3.41 U	3.41 U	3.00 U	3.49 U
C2-Phenanthrenes/Anthracenes	3.41 U	3.41 U	3.00 U	3.49 U
C3-Phenanthrenes/Anthracenes	3.41 U	3.41 U	3.00 U	3.49 U
C4-Phenanthrenes/Anthracenes	3.41 U	3.41 U	3.00 U	3.49 U
1-Methylphenanthrene	3.93 U	3.93 U	3.46 U	4.02 U
Dibenzothiophene	4.21 U	4.21 U	3.71 U	4.31 U
C1-Dibenzothiophenes	4.21 U	4.21 U	3.71 U	4.31 U
C2-Dibenzothiophenes	4.21 U	4.21 U	3.71 U	4.31 U
C3-Dibenzothiophenes	4.21 U	4.21 U	3.71 U	4.31 U
Fluoranthene	2.12 J	3.86 J	6.33 J	4.09 U
Pyrene	2.65 J	3.03 J	4.13 J	4.45 U
C1-Fluoranthenes/Pyrenes	4.00 U	4.00 U	13.20 J	4.09 U
C2-Fluoranthenes/Pyrenes	4.00 U	4.00 U	3.52 U	4.09 U
C3-Fluoranthenes/Pyrenes	4.00 U	4.00 U	3.52 U	4.09 U
Benzo(a)anthracene	6.31 U	6.31 U	5.55 U	6.46 U
Chrysene	3.33 U	3.33 U	2.93 U	3.40 U
C1-Chrysenes	3.33 U	3.33 U	2.93 U	3.40 U
C2-Chrysenes	3.33 U	3.33 U	2.93 U	3.40 U
C3-Chrysenes	3.33 U	3.33 U	2.93 U	3.40 U
C4-Chrysenes	3.33 U	3.33 U	2.93 U	3.40 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W02-745MSvalues.xls



Project Name SPAWAI  
Project Number G60011

Client Sample ID	SLA-SMA-3-PAHs	SLA-SMA-Comp45-PAHs	SLA-SMA-6-PAHs	SLB-SMB-2-PAHs
Battelle Sample ID	U2225	U2226	U2227	U2228
Battelle Batch ID	02-745	02-745	02-745	02-745
Data File	A1762.D	A1764.D	A1765.D	A1766.D
Extraction Date	12/26/02	12/26/02	12/26/02	12/26/02
Acquired Date	3/3/03	3/3/03	3/3/03	3/3/03
Matrix	Water	Water	Water	Water
Sample Size	0.22 L	0.22 L	0.25 L	0.215 L
Dilution Factor	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1 mL
Min Reporting Limit	75.77	75.77	66.68	77.53
Amount Units	ng/L	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	8.87 J	3.90 U	7.93 J	3.99 U
Benzo(k)fluoranthene	5.38 J	3.94 U	4.93 J	4.03 U
Benzo(e)pyrene	7.80 J	4.12 U	3.63 U	4.22 U
Benzo(a)pyrene	10.00 J	5.90 U	5.19 U	6.04 U
Perylene	6.35 U	6.35 U	5.59 U	6.50 U
Indeno(1,2,3-c,d)pyrene	8.30 U	8.30 U	7.30 U	8.49 U
Dibenz(a,h)anthracene	9.48 U	9.48 U	8.34 U	9.70 U
Benzo(g,h,i)perylene	5.14 U	5.14 U	4.52 U	5.26 U
Naphthalene-d8	60	62	61	77
Phenanthrene-d10	72	75	72	75
Chrysene-d12	79	83	79	79

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p





Project Name SPAWAI  
Project Number G60011;

Client Sample ID	SLB-SMB-3-PAHs	SLB-SMB-Comp45-PAHs	SLB-SMB-6-PAHs	Duxbury Water
Battelle Sample ID	U2229	U2230	U2231	U2211
Battelle Batch ID	02-745	02-745	02-745	02-739
Data File	A1767.D	A1768.D	A1769.D	A1180.D
Extraction Date	12/26/02	12/26/02	12/26/02	12/20/02
Acquired Date	3/3/03	3/3/03	3/3/03	01/22/03
Matrix	Water	Water	Water	Water
Sample Size	0.24 L	0.24 L	0.21 L	1.00 L
Dilution Factor	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1.00 mL
Min Reporting Limit	69.46	69.46	79.38	16.67
Amount Units	ng/L	ng/L	ng/L	ng/L
Naphthalene	26.88 J	23.89 J	28.74 J	14.24 J
C1-Naphthalenes	10.00 J	8.47 J	6.27 J	7.67 J
C2-Naphthalenes	139.76 U	139.76 U	159.72 U	33.54 U
C3-Naphthalenes	139.76 U	139.76 U	159.72 U	33.54 U
C4-Naphthalenes	139.76 U	139.76 U	159.72 U	33.54 U
2-Methylnaphthalene	7.08 J	5.35 J	4.29 J	6.83 J
1-Methylnaphthalene	4.17 J	3.96 J	3.97 J	4.50 J
2,6-Dimethylnaphthalene	3.95 U	3.95 U	4.52 U	0.95 U
2,3,5-Trimethylnaphthalene	4.15 U	4.15 U	4.75 U	1.00 U
Biphenyl	2.01 J	3.82 J	3.18 J	1.75 J
Acenaphthylene	3.45 U	3.45 U	3.94 U	0.82 J
Acenaphthene	4.46 U	4.46 U	5.10 U	1.05 J
Fluorene	4.08 U	4.08 U	4.67 U	1.47 J
C1-Fluorenes	4.08 U	4.08 U	4.67 U	0.98 U
C2-Fluorenes	4.08 U	4.08 U	4.67 U	0.98 U
C3-Fluorenes	4.08 U	4.08 U	4.67 U	0.98 U
Phenanthrene	3.75 J	2.29 J	3.73 J	5.72 J
Anthracene	2.90 U	2.90 U	3.32 U	0.70 U
C1-Phenanthrenes/Anthracenes	3.13 U	3.13 U	3.57 U	0.75 U
C2-Phenanthrenes/Anthracenes	3.13 U	3.13 U	3.57 U	0.75 U
C3-Phenanthrenes/Anthracenes	3.13 U	3.13 U	3.57 U	0.75 U
C4-Phenanthrenes/Anthracenes	3.13 U	3.13 U	3.57 U	0.75 U
1-Methylphenanthrene	3.60 U	3.60 U	4.12 U	0.87 U
Dibenzothiophene	3.86 U	3.86 U	4.41 U	2.50 J
C1-Dibenzothiophenes	3.86 U	3.86 U	4.41 U	0.93 U
C2-Dibenzothiophenes	3.86 U	3.86 U	4.41 U	0.93 U
C3-Dibenzothiophenes	3.86 U	3.86 U	4.41 U	0.93 U
Fluoranthene	2.15 J	3.06 J	3.10 J	5.62 J
Pyrene	2.15 J	1.94 J	2.30 J	4.95 J
C1-Fluoranthenes/Pyrenes	3.67 U	3.67 U	4.19 U	0.88 U
C2-Fluoranthenes/Pyrenes	3.67 U	3.67 U	4.19 U	0.88 U
C3-Fluoranthenes/Pyrenes	3.67 U	3.67 U	4.19 U	0.88 U
Benzo(a)anthracene	5.79 U	5.79 U	6.61 U	1.07 J
Chrysene	3.05 U	3.05 U	3.48 U	3.38 J
C1-Chrysenes	3.05 U	3.05 U	3.48 U	0.73 U
C2-Chrysenes	3.05 U	3.05 U	3.48 U	0.73 U
C3-Chrysenes	3.05 U	3.05 U	3.48 U	0.73 U
C4-Chrysenes	3.05 U	3.05 U	3.48 U	0.73 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W02-745MSvalues .xls



Project Name SPAWAI  
Project Number G60011

Client Sample ID	SLB-SMB-3-PAHs	SLB-SMB-Comp45-PAHs	SLB-SMB-6-PAHs	Duxbury Water
Battelle Sample ID	U2229	U2230	U2231	U2211
Battelle Batch ID	02-745	02-745	02-745	02-739
Data File	A1767.D	A1768.D	A1769.D	A1180.D
Extraction Date	12/26/02	12/26/02	12/26/02	12/20/02
Acquired Date	3/3/03	3/3/03	3/3/03	01/22/03
Matrix	Water	Water	Water	Water
Sample Size	0.24 L	0.24 L	0.21 L	1.00 L
Dilution Factor	1.667	1.667	1.667	1.667
PIV	1 mL	1 mL	1 mL	1.00 mL
Min Reporting Limit	69.46	69.46	79.38	16.67
Amount Units	ng/L	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	3.58 U	3.58 U	4.09 U	0.86 U
Benzo(k)fluoranthene	3.61 U	3.61 U	4.13 U	0.87 U
Benzo(e)pyrene	3.78 U	3.78 U	4.32 U	0.91 U
Benzo(a)pyrene	5.41 U	5.41 U	6.18 U	1.30 U
Perylene	5.82 U	5.82 U	6.65 U	1.40 U
Indeno(1,2,3-c,d)pyrene	7.61 U	7.61 U	8.69 U	1.83 U
Dibenz(a,h)anthracene	8.69 U	8.69 U	9.93 U	2.09 U
Benzo(g,h,i)perylene	4.71 U	4.71 U	5.38 U	1.98 J
Naphthalene-d8	76	75	79	55
Phenanthrene-d10	77	77	79	73
Chrysene-d12	80	81	83	80

U = Analyte not detected, the sample s  
J = Analyte detected below the sample  
NA = Not applicable.  
N = QC value outside the accuracy or p



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample Bay Water Spilled with FW21	BPA-BFSD-G1-PAHs	BPA-BFSD-G2-PAHs	BPA-BFSD-G3-PAHs	
Battelle Sample ID	AB950PB	AB951LCS	AB952SRM	U3614	U3615	U3616
Battelle Batch ID	03-0057	03-0057	03-0057	03-0057	03-0057	03-0057
Data File	A1429.D	A1430.D	A1431.D	A1432.D	A1434.D	A1435.D
Extraction Date	01/20/03	01/20/03	01/20/03	01/20/03	01/20/03	01/20/03
Acquired Date	02/02/03	02/02/03	02/02/03	02/02/03	02/02/03	02/03/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	0.245 L	0.23 L	0.225 L
Dilution Factor	1	1	1	1	1	1
PIV	1.8 mL	1 mL	1.8 mL	1 mL	1.8 mL	1.8 mL
Min Reporting Limit	18	10	18	40.82	78.26	80.00
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Naphthalene	20.12 U	606.97	360.44	82.13 U	87.48 U	89.43 U
C1-Naphthalenes	20.12 U	20.12 U	20.12 U	82.13 U	87.48 U	89.43 U
C2-Naphthalenes	20.12 U	20.12 U	20.12 U	82.13 U	87.48 U	89.43 U
C3-Naphthalenes	20.12 U	20.12 U	20.12 U	82.13 U	87.48 U	89.43 U
C4-Naphthalenes	20.12 U	20.12 U	20.12 U	82.13 U	87.48 U	89.43 U
2-Methylnaphthalene	0.59 U	764.89	567.15	2.42 U	2.58 U	2.64 U
1-Methylnaphthalene	0.62 U	768.03	439.09	2.51 U	2.68 U	2.74 U
2,6-Dimethylnaphthalene	0.57 U	833.26	615.53	2.32 U	2.47 U	2.53 U
2,3,5-Trimethylnaphthalene	0.60 U	835.90	765.07	2.44 U	2.60 U	2.66 U
Biphenyl	0.50 U	924.25	606.34	177.63	2.17 U	2.22 U
Acenaphthylene	0.50 U	839.71	792.55	2.02 U	2.16 U	2.20 U
Acenaphthene	0.64 U	857.59	863.71	187.10	194.65	147.96
Fluorene	0.59 U	903.55	928.74	2.40 U	2.56 U	2.61 U
C1-Fluorenes	0.59 U	0.59 U	0.59 U	2.40 U	2.56 U	2.61 U
C2-Fluorenes	0.59 U	0.59 U	0.59 U	2.40 U	2.56 U	2.61 U
C3-Fluorenes	0.59 U	0.59 U	0.59 U	2.40 U	2.56 U	2.61 U
Phenanthrene	0.45 U	919.73	1257.72	1.84 U	1.96 U	2.00 U
Anthracene	0.42 U	762.00	904.13	1.71 U	1.82 U	1.86 U
C1-Phenanthrenes/Anthracenes	0.45 U	0.45 U	0.45 U	1.84 U	1.96 U	2.00 U
C2-Phenanthrenes/Anthracenes	0.45 U	0.45 U	0.45 U	1.84 U	1.96 U	2.00 U
C3-Phenanthrenes/Anthracenes	0.45 U	0.45 U	0.45 U	1.84 U	1.96 U	2.00 U
C4-Phenanthrenes/Anthracenes	0.45 U	0.45 U	0.45 U	1.84 U	1.96 U	2.00 U
1-Methylphenanthrene	0.52 U	915.57	1508.72	2.12 U	2.26 U	2.31 U
Dibenzothiophene	0.56 U	0.56 U	0.56 U	514.00	649.00	696.89
C1-Dibenzothiophenes	0.56 U	0.56 U	0.56 U	2.27 U	2.42 U	2.47 U
C2-Dibenzothiophenes	0.56 U	0.56 U	0.56 U	2.27 U	2.42 U	2.47 U
C3-Dibenzothiophenes	0.56 U	0.56 U	0.56 U	2.27 U	2.42 U	2.47 U
Fluoranthene	0.53 U	910.48	1786.24	134.20	185.83	156.62
Pyrene	0.57 U	948.84	1857.59	2.34 U	2.50 U	2.55 U
C1-Fluoranthenes/Pyrenes	0.53 U	0.53 U	0.53 U	2.16 U	2.30 U	2.35 U
C2-Fluoranthenes/Pyrenes	0.53 U	0.53 U	0.53 U	2.16 U	2.30 U	2.35 U
C3-Fluoranthenes/Pyrenes	0.53 U	0.53 U	0.53 U	2.16 U	2.30 U	2.35 U
Benzo(a)anthracene	0.83 U	976.88	750.38	3.40 U	3.62 U	3.70 U
Chrysene	0.44 U	1138.33	902.55	1.79 U	1.91 U	1.95 U
C1-Chrysenes	0.44 U	0.44 U	0.44 U	1.79 U	1.91 U	1.95 U
C2-Chrysenes	0.44 U	0.44 U	0.44 U	1.79 U	1.91 U	1.95 U
C3-Chrysenes	0.44 U	0.44 U	0.44 U	1.79 U	1.91 U	1.95 U
C4-Chrysenes	0.44 U	0.44 U	0.44 U	1.79 U	1.91 U	1.95 U

Not Surrogate Corrected  
Final results

Prepared by Yuanxue Hou  
6/20/2006

W03-0057MSvalues.xls



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Procedural Blank	Laboratory Control Sample Bay	Water Spilked with FW21	BPA-BFSD-G1-PAHs	BPA-BFSD-G2-PAHs	BPA-BFSD-G3-PAHs
Battelle Sample ID	AB950PB	AB951LCS	AB952SRM	U3614	U3615	U3616
Battelle Batch ID	03-0057	03-0057	03-0057	03-0057	03-0057	03-0057
Data File	A1429.D	A1430.D	A1431.D	A1432.D	A1434.D	A1435.D
Extraction Date	01/20/03	01/20/03	01/20/03	01/20/03	01/20/03	01/20/03
Acquired Date	02/02/03	02/02/03	02/02/03	02/02/03	02/02/03	02/03/03
Matrix	Water	Water	Water	Water	Water	Water
Sample Size	1 L	1 L	1 L	0.245 L	0.23 L	0.225 L
Dilution Factor	1	1	1	1	1	1
PIV	1.8 mL	1 mL	1.8 mL	1 mL	1.8 mL	1.8 mL
Min Reporting Limit	18	10	18	40.82	78.26	80.00
Amount Units	ng/L	ng/L	ng/L	ng/L	ng/L	ng/L
Benzo(b)fluoranthene	0.52 U	1007.87	1131.82	2.10 U	2.24 U	2.29 U
Benzo(k)fluoranthene	0.52 U	1183.11	1135.60	2.12 U	2.26 U	2.31 U
Benzo(e)pyrene	0.54 U	1070.99	1088.82	2.22 U	2.37 U	2.42 U
Benzo(a)pyrene	0.78 U	927.39	922.61	3.18 U	3.39 U	3.46 U
Perylene	0.84 U	904.73	763.28	3.42 U	3.64 U	3.72 U
Indeno(1,2,3-c,d)pyrene	1.10 U	763.69	929.59	4.47 U	4.76 U	4.87 U
Dibenz(a,h)anthracene	1.25 U	872.37	911.69	5.11 U	5.44 U	5.56 U
Benzo(g,h,i)perylene	0.68 U	1068.75	1067.66	2.77 U	2.95 U	3.01 U
Naphthalene-d8	39	61	32	26 N	16 N	40
Phenanthrene-d10	101	80	103	86	98	104
Chrysene-d12	89	108	84	81	86	85

U = Analyte not detected, the sample specific Method Detection Limit reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.



Project Name SPAWAR  
Project Number G600112

Client Sample ID	BPA-BFSD-G4-PAHs
Battelle Sample ID	U3617
Battelle Batch ID	03-0057
Data File	A1436.D
Extraction Date	01/20/03
Acquired Date	02/03/03
Matrix	Water
Sample Size	0.225 L
Dilution Factor	1
PIV	1 mL
Min Reporting Limit	44.44
Amount Units	ng/L
<hr/>	
Naphthalene	89.43 U
C1-Naphthalenes	89.43 U
C2-Naphthalenes	89.43 U
C3-Naphthalenes	89.43 U
C4-Naphthalenes	89.43 U
2-Methylnaphthalene	2.64 U
1-Methylnaphthalene	2.74 U
2,6-Dimethylnaphthalene	2.53 U
2,3,5-Trimethylnaphthalene	2.66 U
Biphenyl	15.11 J
Acenaphthylene	2.20 U
Acenaphthene	43.29 J
Fluorene	2.61 U
C1-Fluorenes	2.61 U
C2-Fluorenes	2.61 U
C3-Fluorenes	2.61 U
Phenanthrene	17.64 J
Anthracene	11.96 J
C1-Phenanthrenes/Anthracenes	2.00 U
C2-Phenanthrenes/Anthracenes	2.00 U
C3-Phenanthrenes/Anthracenes	2.00 U
C4-Phenanthrenes/Anthracenes	2.00 U
1-Methylphenanthrene	2.31 U
Dibenzothiophene	404.00
C1-Dibenzothiophenes	2.47 U
C2-Dibenzothiophenes	2.47 U
C3-Dibenzothiophenes	2.47 U
Fluoranthene	60.27
Pyrene	8.27 J
C1-Fluoranthenes/Pyrenes	2.35 U
C2-Fluoranthenes/Pyrenes	2.35 U
C3-Fluoranthenes/Pyrenes	2.35 U
Benzo(a)anthracene	5.24 J
Chrysene	13.42 J
C1-Chrysenes	1.95 U
C2-Chrysenes	1.95 U
C3-Chrysenes	1.95 U
C4-Chrysenes	1.95 U



Project Name SPAWAR  
Project Number G600112

Client Sample ID	BPA-BFSD-G4-PAHs
Battelle Sample ID	U3617
Battelle Batch ID	03-0057
Data File	A1436.D
Extraction Date	01/20/03
Acquired Date	02/03/03
Matrix	Water
Sample Size	0.225 L
Dilution Factor	1
PIV	1 mL
Min Reporting Limit	44.44
Amount Units	ng/L
Benzo(b)fluoranthene	2.29 U
Benzo(k)fluoranthene	2.31 U
Benzo(e)pyrene	2.42 U
Benzo(a)pyrene	3.46 U
Perylene	3.72 U
Indeno(1,2,3-c,d)pyrene	4.87 U
Dibenz(a,h)anthracene	5.56 U
Benzo(g,h,i)perylene	3.01 U
Naphthalene-d8	51
Phenanthrene-d10	61
Chrysene-d12	89

U = Analyte not detected, the sample spec  
J = Analyte detected below the sample spec  
NA = Not applicable.  
N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

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Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision





Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID  
Battelle Batch ID  
Data File  
Extraction Date  
Acquired Date  
Matrix  
Sample Size  
Dilution Factor  
PIV  
Min Reporting Limit  
Amount Units

---

Benzo(b)fluoranthene  
Benzo(k)fluoranthene  
Benzo(e)pyrene  
Benzo(a)pyrene  
Perylene  
Indeno(1,2,3-c,d)pyrene  
Dibenz(a,h)anthracene  
Benzo(g,h,i)perylene

---

Naphthalene-d8  
Phenanthrene-d10  
Chrysene-d12

U = Analyte not detected, the sample size  
J = Analyte detected below the sample size  
NA = Not applicable.  
N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID  
Battelle Batch ID  
Data File  
Extraction Date  
Acquired Date  
Matrix  
Sample Size  
Dilution Factor  
PIV  
Min Reporting Limit  
Amount Units

---

Benzo(b)fluoranthene  
Benzo(k)fluoranthene  
Benzo(e)pyrene  
Benzo(a)pyrene  
Perylene  
Indeno(1,2,3-c,d)pyrene  
Dibenz(a,h)anthracene  
Benzo(g,h,i)perylene

---

Naphthalene-d8  
Phenanthrene-d10  
Chrysene-d12

U = Analyte not detected, the sample size  
J = Analyte detected below the sample size  
NA = Not applicable.  
N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision





Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision



Project Name	SPAWAR
Project Number	G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Naphthalene

C1-Naphthalenes

C2-Naphthalenes

C3-Naphthalenes

C4-Naphthalenes

2-Methylnaphthalene

1-Methylnaphthalene

2,6-Dimethylnaphthalene

2,3,5-Trimethylnaphthalene

Biphenyl

Acenaphthylene

Acenaphthene

Fluorene

C1-Fluorenes

C2-Fluorenes

C3-Fluorenes

Phenanthrene

Anthracene

C1-Phenanthrenes/Anthracenes

C2-Phenanthrenes/Anthracenes

C3-Phenanthrenes/Anthracenes

C4-Phenanthrenes/Anthracenes

1-Methylphenanthrene

Dibenzothiophene

C1-Dibenzothiophenes

C2-Dibenzothiophenes

C3-Dibenzothiophenes

Fluoranthene

Pyrene

C1-Fluoranthenes/Pyrenes

C2-Fluoranthenes/Pyrenes

C3-Fluoranthenes/Pyrenes

Benzo(a)anthracene

Chrysene

C1-Chrysenes

C2-Chrysenes

C3-Chrysenes

C4-Chrysenes



Project Name SPAWAR  
Project Number G600112

Client Sample ID

Battelle Sample ID

Battelle Batch ID

Data File

Extraction Date

Acquired Date

Matrix

Sample Size

Dilution Factor

PIV

Min Reporting Limit

Amount Units

---

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Benzo(e)pyrene

Benzo(a)pyrene

Perylene

Indeno(1,2,3-c,d)pyrene

Dibenz(a,h)anthracene

Benzo(g,h,i)perylene

---

Naphthalene-d8

Phenanthrene-d10

Chrysene-d12

U = Analyte not detected, the sample size

J = Analyte detected below the sample size

NA = Not applicable.

N = QC value outside the accuracy or precision





Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID Duxbury Water

Battelle Sample ID	U2211
Battelle Batch ID	03-0003
Data File	A1180.D
Extraction Date	12/20/02
Acquired Date	01/22/03
Matrix	Water
Sample Size	1.00 L
Dilution Factor	1.667
PIV	1.00 mL
Min Reporting Limit	16.67
Amount Units	ng/L

Naphthalene	14.24 J
C1-Naphthalenes	7.67 J
C2-Naphthalenes	33.54 U
C3-Naphthalenes	33.54 U
C4-Naphthalenes	33.54 U
2-Methylnaphthalene	6.83 J
1-Methylnaphthalene	4.50 J
2,6-Dimethylnaphthalene	0.95 U
2,3,5-Trimethylnaphthalene	1.00 U
Biphenyl	1.75 J
Acenaphthylene	0.82 J
Acenaphthene	1.05 J
Fluorene	1.47 J
C1-Fluorenes	0.98 U
C2-Fluorenes	0.98 U
C3-Fluorenes	0.98 U
Phenanthrene	5.72 J
Anthracene	0.70 U
C1-Phenanthrenes/Anthracenes	0.75 U
C2-Phenanthrenes/Anthracenes	0.75 U
C3-Phenanthrenes/Anthracenes	0.75 U
C4-Phenanthrenes/Anthracenes	0.75 U
1-Methylphenanthrene	0.87 U
Dibenzothiophene	2.50 J
C1-Dibenzothiophenes	0.93 U
C2-Dibenzothiophenes	0.93 U
C3-Dibenzothiophenes	0.93 U
Fluoranthene	5.62 J
Pyrene	4.95 J
C1-Fluoranthenes/Pyrenes	0.88 U
C2-Fluoranthenes/Pyrenes	0.88 U
C3-Fluoranthenes/Pyrenes	0.88 U
Benzo(a)anthracene	1.07 J
Chrysene	3.38 J
C1-Chrysenes	0.73 U
C2-Chrysenes	0.73 U
C3-Chrysenes	0.73 U
C4-Chrysenes	0.73 U



Project Name SPAWAR TO0009 - SPAWAR Task Order 0009 PRISM Demo II, Pearl Harbor  
Project Number G600112

Client Sample ID	Duxbury Water
Battelle Sample ID	U2211
Battelle Batch ID	03-0003
Data File	A1180.D
Extraction Date	12/20/02
Acquired Date	01/22/03
Matrix	Water
Sample Size	1.00 L
Dilution Factor	1.667
PIV	1.00 mL
Min Reporting Limit	16.67
Amount Units	ng/L
<hr/>	
Benzo(b)fluoranthene	0.86 U
Benzo(k)fluoranthene	0.87 U
Benzo(e)pyrene	0.91 U
Benzo(a)pyrene	1.30 U
Perylene	1.40 U
Indeno(1,2,3-c,d)pyrene	1.83 U
Dibenz(a,h)anthracene	2.09 U
Benzo(g,h,i)perylene	1.98 J
<hr/>	
Naphthalene-d8	55
Phenanthrene-d10	73
Chrysene-d12	82

U = Analyte not detected, the sample specific Method Detection Limit reported.

J = Analyte detected below the sample specific Reporting Limit (RL).

NA = Not applicable.

N = QC value outside the accuracy or precision data quality objective.

## CHNS Analysis

### Pearl Harbor - Bishop Point composite sediments and sediment cores

OC = organic carbon, inorganic carbon (as carbonates) removed by acid digestion with 6 N HCl

TC = total carbon

Sample	% C	% H	% N	% S	S.D.				Atomic C/N
					C	H	N	S	
BPA-cpsd-OC-U	3.78	2.29	0.47	1.02	0.19	0.24	0.02	0.05	9.49
BPB-cpsd-OC-U	1.45	2.07	0.20	0.61	0.10	0.49	0.07	0.22	8.94
BPC-cpsd-OC-U	1.07	1.79	0.15	0.76	0.07	0.40	0.03	0.33	8.35
BPA-cpsd-OC-L	4.23	2.67	0.49	1.35	0.52	0.07	0.11	0.04	10.28
BPB-cpsd-OC-L	1.26	1.88	0.18	0.69	0.13	0.32	0.07	0.04	9.25
BPC-cpsd-OC-L	1.00	1.63	0.15	0.79	0.02	0.34	0.11	0.35	10.83
BPA-cpsd-TC-U	12.33	1.17	0.30	0.95					47.95
BPB-cpsd-TC-U	10.73	0.64	0.14	0.50					89.42
BPC-cpsd-TC-U	10.75	0.52	0.16	0.31					78.39
BPA-cpsd-TC-L	11.72	1.16	0.24	0.87					56.97
BPB-cpsd-TC-L	10.65	0.41	0.13	0.09					95.58
BPC-cpsd-TC-L	10.75	0.51	0.11	0.04					114.02
BPA-STs-OC	2.21	3.07	0.29	0.62	0.05	0.00	0.04	0.10	8.95
BPB-STs-OC	1.92	2.89	0.24	0.55	0.04	0.05	0.01	0.05	9.33
BPC-STs-OC	2.08	2.60	0.25	0.93	0.00	0.12	0.03	0.07	9.77
BPA-STs-TC	10.63	1.09	0.30	0.48					41.34
BPB-STs-TC	10.96	1.00	0.25	0.34					51.15
BPC-STs-TC	11.00	1.01	0.30	0.60					42.78
BPC-ltsd-TOC (0-2)	1.05	2.69	-0.01	0.65					-122.50
BPC-ltsd-TOC (2-4)	0.92	2.73	N/A	N/A					N/A
BPC-ltsd-TOC (4-6)	1.24	2.71	0.17	2.49					8.51
BPC-ltsd-TOC (6-8)	1.03	2.72	0.06	1.19					20.03
BPC-ltsd-TOC (8-10)	1.01	2.66	0.16	0.77					7.36
BPC-ltsd-TOC (10-15)	0.81	2.64	0.04	0.89					23.63
BPC-ltsd-TOC (20-25)	0.57	2.67	-0.13	0.76					-5.12
BPC-ltsd-TOC (30-35)	0.12	2.35	0.06	0.16					2.33
BPC-ltsd-TOC (40-45)	0.14	2.54	-0.16	0.44					-1.02
BPC-ltsd-TOC (50-55)	0.11	2.49	-0.07	0.56					-1.83

PRISM II Grain Size Analysis

**NOTE: THIS PACKAGE CONTAINS RESULTS OF SEDIMENT**

**ORGANICS PROCESSING UNDER CONTRACT N66001-02-D-0017 - TASK ORDER TO0009**

	Gravel	Sand	Silt	Clay	TOC
BPA-cpsd-PAH-U	3.34	23.11	37.52	36.03	15.67
BPA-cpsd-PAH-L	3.33	22.74	37.73	36.21	15.30
BPB-cpsd-PAH-U	0.29	39.24	31.67	28.80	9.91
BPB-cpsd-PAH-L	0.98	42.96	28.73	27.33	7.14
BPC-cpsd-PAH-U	3.35	44.00	28.50	24.15	8.50
BPC-cpsd-PAH-L	2.71	45.67	28.60	23.02	8.07
SLA-cpsd-PAH-U	3.62	22.87	31.88	41.63	7.28
SLA-cpsd-PAH-L	1.70	32.89	30.02	35.38	6.60
SLB-cpsd-PAH-U	0.40	9.76	38.22	51.61	6.27
SLB-cpsd-PAH-L	0.48	14.52	36.90	48.10	6.42
SLC-cpsd-PAH-U	0.60	6.04	40.25	53.10	5.56
SLC-cpsd-PAH-L	2.18	8.435	41.05	48.34	5.29

# Surface Area Analysis

PRISM - Pearl Harbor

Sample Name	Specific Surface			Density		
	Area (m <sup>2</sup> /g)	S.D.	R.S.D.	(g/ml)	S.D.	R.S.D.
BPA-cpsd-SSA/density-U	9.45	1.10	11.7	2.62	0.13	5.1
BPB-cpsd-SSA/density-U	8.47	0.51	6.0	2.64	0.09	3.5
BPC-cpsd-SSA/density-U	7.94	0.33	4.2	2.59	0.03	1.1
BPA-cpsd-SSA/density-L	10.07	0.14	1.4	2.61	0.03	1.1
BPB-cpsd-SSA/density-L	8.62	0.12	1.4	2.75	0.02	0.8
BPC-cpsd-SSA/density-L	7.55	0.42	5.5	2.77	0.11	4.1
BPA-STs-SSA/Density	10.25	0.35	3.4	2.54	0.11	4.5
BPB-STs-SSA/Density	9.27	0.45	4.8	2.59	0.30	11.5
BPC-STs-SSA/Density	10.13	0.40	3.9	2.68	0.04	1.6

# Surface Area Analysis

PRISM - Pearl Harbor

Sample Name	Specific Surface			Density		
	Area (m <sup>2</sup>	S.D.	R.S.D.	(g/ml)	S.D.	R.S.D.
SLA-cpsd-SSA/density-U						66.93
SLB-cpsd-SSA/density-U						70.13
SLC-cpsd-SSA/density-U						71.61
SLA-cpsd-SSA/density-L						72.36
SLB-cpsd-SSA/density-L						69.10
SLC-cpsd-SSA/density-L						72.71
SLA-STs-SSA/Density						61.46
SLB-STs-SSA/Density	2.56					58.03
SLC-STs-SSA/Density	2.80					65.18

## CHNS Analysis

### Pearl Harbor - Southeast Loch composite sediments and sediment cores

OC = organic carbon, inorganic carbon (as carbonates) removed by acid digestion with 6 N HCl

TC = total carbon

Sample	% C	% H	% N	% S	S.D.				Atomic C/N
					C	H	N	S	
SLA-cpsd-OC-U	2.71	2.61	0.19	1.73	0.10	0.19	0.05	0.52	17.50
SLB-cpsd-OC-U	2.75	2.89	0.21	1.93	0.01	0.61	0.04	0.10	15.89
SLC-cpsd-OC-U	2.18	2.55	0.25	1.75	0.05	0.22	0.13	0.18	11.88
SLA-cpsd-OC-L	2.46	2.26	0.20	2.20	0.10	0.43	0.04	1.14	14.44
SLB-cpsd-OC-L	2.43	2.84	0.21	1.95	0.03	0.20	0.03	0.11	13.61
SLC-cpsd-OC-L	2.14	3.23	0.17	1.93	0.03	0.08	0.00	0.02	14.69
SLA-cpsd-TC-U	8.40	1.43	0.20	1.25					49.00
SLB-cpsd-TC-U	8.00	1.54	0.21	1.26					44.44
SLC-cpsd-TC-U	7.35	1.65	0.18	1.48					47.64
SLA-cpsd-TC-L	8.28	1.45	0.17	1.39	0.04	0.14		1.04	57.03
SLB-cpsd-TC-L	8.01	1.39	0.19	1.25					49.18
SLC-cpsd-TC-L	7.32	1.41	0.13	1.43					65.69
SLA-STs-OC	3.44	2.37	0.34	1.50	0.02	0.18	0.06	0.67	12.14
SLB-STs-OC	3.79	2.84	0.36	2.32	0.02	0.12	0.04	1.15	12.35
SLC-STs-OC	3.38	2.82	0.35	1.21	0.01	0.02	0.01	0.08	11.43
SLA-STs-TC	7.88	1.94	0.33	0.85					27.86
SLB-STs-TC	8.95	2.09	0.52	1.00					20.08
SLC-STs-TC	8.02	1.61	0.38	0.98					24.62
SLC-ltsd-TOC (0-2)	2.08	2.32	0.18	1.13					13.48
SLC-ltsd-TOC (2-4)	2.05	2.46	0.18	1.79					13.29
SLC-ltsd-TOC (4-6)	2.00	2.30	0.13	1.70					17.95
SLC-ltsd-TOC (6-8)	1.73	2.61	0.12	1.62					16.82
SLC-ltsd-TOC (10-15)	1.70	2.73	0.12	1.53					16.53
SLC-ltsd-TOC (20-25)	1.82	2.46	0.19	2.27					11.18
SLC-ltsd-TOC (30-35)	2.08	2.53	0.17	2.69					14.27
SLC-ltsd-TOC (40-45)	1.55	2.79	0.11	1.07					16.44
SLC-ltsd-TOC (50-55)	1.59	2.90	0.06	0.97					30.92
SLC-ltsd-TOC (55-60)	1.20	2.50	-0.02	0.87					-70.00

Battelle Marine Sciences Laboratory  
 1529 West Sequim Bay Rd.  
 Sequim, WA 98382  
 (360) 683-4151  
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**Cs-137 Results in Sediments**  
**SPAWARS PRISM**

				Percent		Cs 137 dis/min/g (dry wt.)	SRM CERTIFIED VALUE dis/min/g	%RPD
BATTELLE Core CODE	ID	SPONSOR CODE	Depth (cm)	Dry Wt. (g)	Dry Wt. (g)			
IAEA-135	NA	IAEA 135	NA	11.0	NA	50.3	53.6	7%
1939*1	BPC-ltsd	BPC-ltsd-BeCs (0-1)	0-1	15.2	51.4	0.332 U		
1939*2	BPC-ltsd	BPC-ltsd-BeCs(1-2)	1-2	22.1	51.0	0.274 U		
1939*3	BPC-ltsd	BPC-ltsd-BeCs (2-4)	2-4	54.9	56.0	0.168		
1939*4	BPC-ltsd	BPC-ltsd-BeCs (4-6)	4-6	54.8	57.0	0.115 U		
1939*5	BPC-ltsd	BPC-ltsd-BeCs (6-8)	6-8	53.5	57.5	0.119		
1939*6	BPC-ltsd	BPC-ltsd-BeCs (8-10)	8-10	74.2	59.2	0.124 U		
1939*7	BPC-ltsd	BPC-ltsd-BeCs (10-12)	10-12	49.9	58.1	0.147 U		
1939*8	BPC-ltsd	BPC-ltsd-BeCs (14-16)	14-16	65.0	61.6	0.086		
1939*9	BPC-ltsd	BPC-ltsd-BeCs (18-20)	18-20	67.8	64.5	0.131 U		
1939*10	BPC-ltsd	BPC-ltsd-BeCs (21-23)	21-23	57.9	66.2	0.105 U		
1939*21	SLC-ltsd	SLC-ltsd-BeCs (0-1)	0-1	13.3	30.1	0.621 U		
1939*22	SLC-ltsd	SLC-ltsd-BeCs (1-2)	1-2	11.9	32.1	0.568 U		
1939*23	SLC-ltsd	SLC-ltsd-BeCs (2-4)	2-4	23.7	31.6	0.367 U		
1939*24	SLC-ltsd	SLC-ltsd-BeCs (4-6)	4-6	22.1	32.4	0.322 U		
1939*25	SLC-ltsd	SLC-ltsd-BeCs (6-8)	6-8	26.3	34.6	0.323		
1939*26	SLC-ltsd	SLC-ltsd-BeCs (8-10)	8-10	26.0	36.1	0.267 U		
1939*27 R1	SLC-ltsd	SLC-ltsd-BeCs (10-12)	10-12	28.5	36.6	0.320		
1939*27 R2	SLC-ltsd	SLC-ltsd-BeCs (10-12)	10-12	28.5	36.6	0.260 U		
1939*28	SLC-ltsd	SLC-ltsd-BeCs (14-16)	14-16	46.6	42.9	0.149 U		
1939*29	SLC-ltsd	SLC-ltsd-BeCs (18-20)	18-20	38.6	43.9	0.192 U		
1939*30	SLC-ltsd	SLC-ltsd-BeCs (22-24)	22-24	56.9	44.5	0.124 U		
IAEA-135	NA	IAEA 135	NA	11.0	NA	49.1	53.6	9%

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 1529 West Sequim Bay Rd.  
 Sequim, WA 98382  
 (360) 683-4151  
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**Be-7 Results in Sediments**  
**SPAWARS PRISM**

				Percent Dry Wt. (g)	Be 7 counts/min/ g
BATTELL Core CODE	ID	SPONSOR CODE	Depth (cm)		
Be std	NA	NA	NA	80.0	0.0028
1939*1	BPC-ltscBPC-ltsd-BeCs (0-1)		0-1	51.4	0.0024 U
1939*2	BPC-ltscBPC-ltsd-BeCs(1-2)		1-2	51.0	0.0023 U
1939*3	BPC-ltscBPC-ltsd-BeCs (2-4)		2-4	31.6	0.0022 U
1939*4	BPC-ltscBPC-ltsd-BeCs (4-6)		4-6	57.0	-0.0003 U
1939*5	BPC-ltscBPC-ltsd-BeCs (6-8)		6-8	57.5	0.0002 U
1939*6	BPC-ltscBPC-ltsd-BeCs (8-10)		8-10	59.2	0.0005
1939*7	BPC-ltscBPC-ltsd-BeCs (10-12)		10-12	58.1	-0.0004 U
1939*8	BPC-ltscBPC-ltsd-BeCs (14-16)		14-16	61.6	0.0004 U
1939*9	BPC-ltscBPC-ltsd-BeCs (18-20)		18-20	64.5	0.0013
1939*10	BPC-ltscBPC-ltsd-BeCs (21-23)		21-23	66.2	0.0007
1939*21	SLC-ltscSLC-ltsd-BeCs (0-1)		0-1	30.1	-0.0035 U
1939*22	SLC-ltscSLC-ltsd-BeCs (1-2)		1-2	32.1	-0.0013 U
1939*23	SLC-ltscSLC-ltsd-BeCs (2-4)		2-4	56.0	0.0011
1939*24	SLC-ltscSLC-ltsd-BeCs (4-6)		4-6	32.4	0.0009 U
1939*25	SLC-ltscSLC-ltsd-BeCs (6-8)		6-8	34.6	-0.0019 U
1939*26	SLC-ltscSLC-ltsd-BeCs (8-10)		8-10	36.1	-0.0010 U
1939*27 R	SLC-ltscSLC-ltsd-BeCs (10-12)		10-12	36.6	0.0000 U
1939*27 R	SLC-ltscSLC-ltsd-BeCs (10-12)		10-12	36.6	-0.0008 U
1939*28	SLC-ltscSLC-ltsd-BeCs (14-16)		14-16	42.9	-0.0015 U
1939*29	SLC-ltscSLC-ltsd-BeCs (18-20)		18-20	43.9	0.0003 U
1939*30	SLC-ltscSLC-ltsd-BeCs (22-24)		22-24	44.5	0.0002 U
Be std	NA	NA	NA	80.0	0.0032



Battelle Marine Sciences Laboratory  
 1529 West Sequim Bay Rd.  
 Sequim, WA 98382  
 (360) 683-4151

5/16/2003

**SPAWAR Task 9a**  
**Pb-210 RESULTS IN SEDIMENT**

**PROJECT: 1939**

BATTELLE CODE	SPONSOR ID	Depth (cm)	Percent Dry Weight (g)	ACTIVITY	
				Pb210 dpm/g	RPD (%)
BLANK	N/A	N/A	N/A	0.000	
BLANK SPIKED	N/A	N/A	N/A	0.013	
CHECK STD	N/A	N/A	N/A	4.31	25%
1939*11 R1	3PC-ltsd-Pb210 (0-2	0-2	46.5	9.64	
1939*11 R2	3PC-ltsd-Pb210 (0-2	0-2	46.5	11.4	17%
1939*12	3PC-ltsd-Pb210 (2-4	2-4	54.7	17.0	
1939*13	3PC-ltsd-Pb210 (4-6	4-6	56.8	20.1	
1939*14	3PC-ltsd-Pb210 (6-8	6-8	56.3	18.5	
1939*15	3PC-ltsd-Pb210 (8-10	8-10	57.6	18.5	
1939*16	3PC-ltsd-Pb210 (10-1	10-15	61.0	13.9	
1939*17	3PC-ltsd-Pb210 (20-2	20-25	64.1	4.91	
1939*18	3PC-ltsd-Pb210 (30-3	30-35	67.1	4.66	
1939*19	3PC-ltsd-Pb210 (40-4	40-45	69.9	3.53	
1939*20	3PC-ltsd-Pb210 (50-5	50-55	71.4	3.37	
1939*31	3LC-ltsd-Pb210 (0-2	0-2	25.4	6.56	
1939*32	3LC-ltsd-Pb210 (2-4	2-4	34.9	3.04	
1939*33	3LC-ltsd-Pb210 (4-6	4-6	41.1	2.26	
1939*34	3LC-ltsd-Pb210 (6-8	6-8	38.2	1.68	
1939*35	3LC-ltsd-Pb210 (8-10	10-15	41.0	1.17	
1939*36	3LC-ltsd-Pb210 (10-1	20-25	42.0	0.548	
1939*37	3LC-ltsd-Pb210 (20-2	30-35	51.4	0.670	
1939*38	3LC-ltsd-Pb210 (30-3	40-45	56.6	0.875	
1939*39	3LC-ltsd-Pb210 (40-4	50-55	63.8	0.824	
1939*40	3LC-ltsd-Pb210 (50-5	55-60	64.3	0.914	

\*

@

@ = RPD

\* = % difference

LH comp known value = 5.73 dpm/g

Table 3

## Major Element Composition

Core	cm-bsf	CaO %	Al <sub>2</sub> O <sub>3</sub> %	TiO <sub>2</sub> %	Fe <sub>2</sub> O <sub>3</sub> %	K <sub>2</sub> O %	MgO %	SiO <sub>2</sub> %
SLA	0.3	21.3	9.6	1.5	8.2	0.7	3.2	26.5
	0.8	26.3	7.1	1.2	6.9	0.2	2.9	18.8
	1.5	19.1	10.2	1.4	8.2	0.3	3.3	26.8
	2.5	21.8	11.5	1.6	9.0	0.3	3.4	30.4
	3.5	21.4	10.4	1.5	8.7	0.2	3.4	27.9
	4.5	23.0	9.4	1.4	8.2	0.2	3.1	24.9
	5.5	31.9	7.6	1.3	7.3	0.1	3.1	20.4
	6.5	24.2	9.0	1.4	8.0	0.2	3.1	24.8
	7.5	24.0	8.0	1.3	7.6	0.2	3.0	22.2
	8.5	20.6	9.6	1.4	7.9	0.3	3.1	26.0
	9.5	23.7	9.2	1.5	8.4	0.2	3.3	25.4
	10.5	21.4	9.1	1.5	8.5	0.2	3.1	24.5
	11.5	23.8	9.2	1.4	8.1	0.2	3.1	24.7
	12.5	23.3	8.7	1.4	8.1	0.2	3.1	23.8
	13.5	27.5	8.1	1.3	7.7	0.2	2.9	21.3
	14.5	28.7	6.0	1.0	6.3	0.3	2.9	17.0
	16.5	29.8	7.5	1.2	7.1	0.2	2.8	19.7
SLB	0.3	20.7	9.8	1.4	8.2	0.3	2.8	27.0
	0.8	21.1	9.5	1.4	8.3	0.3	2.8	25.8
	1.3	20.9	10.2	1.5	8.5	0.2	3.0	27.5
	1.8	20.9	9.8	1.4	8.3	0.3	2.9	24.8
	2.5	18.1	9.8	1.3	7.5	0.3	2.7	24.3
	3.5	19.9	10.7	1.4	8.3	0.2	3.1	27.3
	4.5	18.7	10.4	1.4	8.0	0.3	3.1	27.5
	6.0	23.3	9.9	1.5	8.0	0.3	3.2	26.7
	7.5	20.0	10.4	1.5	7.4	0.2	3.1	27.7
	9.0	22.0	9.3	1.4	8.3	0.2	3.0	25.1
	10.5	18.7	9.0	1.4	7.2	0.2	2.6	25.5
	12.0	20.2	8.7	1.4	7.7	0.3	2.7	24.3
	13.5	22.7	10.6	1.5	8.1	0.4	3.2	28.2
	15.0	23.2	8.4	1.3	7.7	0.2	2.8	23.1
	16.5	21.6	10.0	1.4	8.1	0.2	3.0	26.6
	18.0	22.0	8.4	1.3	7.5	0.2	2.8	21.6
	19.5	20.3	10.0	1.4	7.9	0.2	3.0	26.9

	21.0	23.3	8.7	1.4	8.1	0.3	3.0	23.3
<b>SLC</b>	0.3	21.0	10.0	1.5	8.4	0.2	2.9	26.0
	0.8	20.8	9.4	1.5	8.4	0.2	2.9	25.6
	1.3	21.6	9.7	1.5	8.7	0.3	3.0	26.3
	1.8	22.4	9.7	1.5	8.6	0.2	3.1	27.2
	2.5	19.6	9.7	1.4	9.0	0.2	2.9	26.3
	6.5	20.9	9.8	1.5	8.6	0.1	3.0	25.9
	7.5	22.6	9.0	1.5	8.4	0.1	3.0	24.4
	8.5	23.0	10.0	1.5	8.6	0.2	3.0	26.2
	9.5	21.6	8.9	1.5	8.0	0.3	3.0	23.9
	10.5	20.1	9.9	1.5	8.6	0.2	3.0	26.1
	11.5	21.6	8.4	1.4	7.8	0.2	2.8	22.6
	12.5	19.0	10.6	1.5	8.4	0.2	3.2	27.5
	13.5	23.6	9.2	1.5	8.4	0.4	3.2	24.3
	14.5	18.6	10.6	1.4	8.2	0.3	3.2	26.6
	16.0	23.3	9.2	1.5	8.5	0.2	3.2	24.8
	17.5	21.1	10.7	1.5	8.1	0.3	3.5	27.3
	19.0	21.9	9.1	1.5	8.5	0.2	3.1	25.0
	20.5	20.0	11.5	1.6	8.6	0.3	3.6	29.3
	14.5	18.6	10.6	1.4	8.2	0.3	3.2	26.6
	16.0	23.3	9.2	1.5	8.5	0.2	3.2	24.8
	17.5	21.1	10.7	1.5	8.1	0.3	3.5	27.3
	19.0	21.9	9.1	1.5	8.5	0.2	3.1	25.0
	20.5	20.0	11.5	1.6	8.6	0.3	3.6	29.3
<b>BPA</b>	0.3	33.4	3.2	0.5	3.3	0.1	2.6	10.8
	0.8	38.0	3.8	0.6	3.8	0.1	3.0	11.9
	1.3	36.4	3.6	0.6	3.6	0.0	2.8	10.9
	1.8	33.8	3.0	0.5	3.3	0.1	2.6	8.8
	2.5	35.6	3.4	0.5	3.6	0.1	2.7	10.1
	4.5	38.2	3.7	0.6	3.4	0.1	3.0	11.4
	5.5	34.2	3.2	0.5	3.1	0.1	2.7	9.1
	6.5	35.9	3.5	0.6	3.5	0.1	2.9	9.8
	7.5	36.5	3.5	0.5	3.5	0.1	2.9	9.1
	8.5	31.3	2.8	0.5	3.6	0.2	2.3	9.2
	9.5	35.9	3.5	0.6	4.0	0.2	2.9	10.9
	10.5	36.7	3.5	0.6	3.8	0.1	2.8	10.3
	12.0	35.2	3.0	0.5	3.3	0.1	2.5	9.8
	13.5	37.2	3.5	0.6	3.7	0.0	2.8	10.7
<b>BPB</b>	0.3	40.3	2.3	0.4	3.1		2.3	7.6
	0.8	41.2	2.3	0.4	2.9	0.1	2.3	7.2
	1.3	40.2	2.4	0.4	3.0	0.1	2.4	7.6

	1.8	42.6	2.6	0.5	3.2	0.1	2.7	8.5
	2.5	42.5	2.3	0.4	2.9	0.0	2.4	7.1
	3.5	43.9	2.6	0.5	3.0	0.0	2.6	8.5
	4.5	40.6	2.4	0.4	2.9	0.0	2.4	8.2
	5.5	40.3	2.4	0.4	3.0	0.1	2.4	8.0
	6.5	38.0	2.2	0.4	2.8		2.3	6.4
	7.5	46.4	2.2	0.4	2.8	0.0	2.3	6.4
	8.5	40.0	2.0	0.4	2.5		2.1	5.5
	9.5	39.9	2.4	0.4	3.0	0.1	2.4	7.4
	10.5	38.9	2.3	0.5	3.0	0.0	2.4	7.2
	12.0	36.8	2.4	0.4	2.9		2.5	7.2
	13.5	38.1	2.3	0.4	2.7	0.0	2.2	6.5
	15.0	37.5	2.3	0.4	2.8	0.0	2.3	6.7
	16.5	40.8	2.7	0.5	3.2	0.0	2.5	7.6
BPC	0.3	41.2	2.3	0.4	3.0	0.2	2.1	6.0
	0.8	42.0	2.1	0.4	2.8		1.9	6.1
	1.3	47.3	2.4	0.5	3.1	0.2	2.1	6.5
	1.8	42.6	2.3	0.5	3.0	0.1	2.0	6.1
	2.5	42.7	2.3	0.5	2.9		2.0	6.6
	3.5	39.8	1.8	0.4	2.5		1.9	5.3
	4.5	43.6	2.1	0.4	2.9		2.0	5.9
	5.5	45.4	2.5	0.5	3.2	0.0	2.2	6.7
	6.5	42.5	2.3	0.5	3.1	0.0	1.9	6.3
	7.5	41.9	1.9	0.4	4.3	0.1	1.8	4.5
	8.5	43.2	2.1	0.4	2.8		1.7	4.9
	9.5	42.4	2.3	0.5	3.0		1.9	5.9
	12.0	42.4	2.4	0.5	3.3	0.1	1.5	5.5
	13.5	41.9	3.4	0.7	4.3	0.2	1.4	7.4
	15.0	40.2	3.1	0.7	3.9	0.1	1.5	7.2

**Table 3**

**Trace Elemental Concentrations**

<b>SAMPLE</b>	<b>cm-bsf</b>	<b>Cr (µg/g)</b>	<b>Mn (µg/g)</b>	<b>Ni (µg/g)</b>	<b>Cu (µg/g)</b>	<b>Zn (µg/g)</b>
<b>SLA</b>	0.25	175	613	76	409	270
	0.75	168	558	72	293	493
	0.75	193	659	76	379	373
	1.50	180	644	87	617	373
	2.50	178	632	82	516	360
	3.50	172	610	86	451	367
	4.50	165	555	68	357	350
	5.50	137	462	52	414	217
	6.50	169	544	46	287	358
	7.50	158	493	55	309	295
	8.50	177	590	73	451	331
	9.50	166	503	67	440	283
	10.50	187	569	74	392	319
	11.50	171	548	71	435	292
	12.50	164	519	55	322	388
	13.50	158	497	69	388	374
	14.50	135	432	55	250	372
	16.50	150	481	56	244	254
<b>SLB</b>	0.25	195	643	70	383	268
	0.75	191	614	84	372	372
	1.25	183	619	85	485	312
	1.75	187	620	86	518	307
	2.50	180	636	74	484	401
	3.50	189	633	88	531	418
	4.50	190	632	89	520	312
	6.00	178	566	40	218	362
	7.50	181	601	46	268	319
	9.00	183	568	30	241	395
	10.50	168	576	42	253	307
	12.00	186	578	69	332	289
	13.50	183	606	77	579	284

	15.00	172	538	58	314	369
	16.50	187	604	70	418	354
	18.00	192	572	64	390	318
	19.50	174	602	81	496	401
	21.00	171	571	104	363	438
<b>SLC</b>	0.25	178	676	65	342	343
	0.75	182	678	61	345	378
	1.25	177	646	70	342	377
	1.75	179	665	59	330	406
	2.50	178	673	68	402	384
	6.50	174	582	77	447	424
	7.50	204	562	76	419	424
	8.50	188	638	82	525	433
	9.50	180	573	59	330	509
	10.50	182	619	77	576	409
	11.50	181	562	65	330	383
	12.50	180	652	80	424	389
	13.50	176	597	64	340	297
	14.50	181	650	85	423	367
	16.00	174	594	69	354	287
	17.50	177	677	83	225	227
	19.00	175	609	84	177	153
	20.50	183	631	89	225	244
<b>BPA</b>	0.25	72	241	29	271	169
	0.75	81	216	31	193	212
	1.25	80	213	28	205	302
	1.75	72	211	28	233	260
	2.50	81	215	32	267	211
	4.50	79	216	31	248	308
	5.50	79	207	40	262	254
	6.50	91	214	33	298	258
	7.50	75	207	30	280	212
	8.50	80	209	34	307	258
	9.50	89	220	43	333	223
	10.50	80	289	32	322	290
	12.00	75	207	27	240	225
	13.50	104	232	30	240	304
<b>BPB</b>	0.25	59	195	34	536	222

0.75	70	188	21	159	224
1.25	62	197	23	208	197
1.75	63	216	23	188	400
2.50	64	184	20	65	190
3.50	59	175	18	63	199
4.50	59	174	24	150	187
5.50	75	178	23	196	213
6.50	57	167	22	169	170
7.50	56	158	23	137	178
8.50	55	159	18	112	194
9.50	65	177	21	194	188
10.50	88	187	24	316	321
12.00	69	179	27	431	166
13.50	72	168	22	216	194
15.00	64	185	24	198	232
16.50	86	189	27	227	285

**BPC**

0.25	59	188	21	207	129
0.75	63	189	20	180	153
1.25	69	199	21	111	430
1.75	65	193	22	110	391
2.50	61	188	27	93	192
3.50	63	179	28	138	131
4.50	59	173	21	123	183
5.50	61	183	25	129	197
6.50	74	194	23	116	165
7.50	126	210	28	196	456
8.50	56	195	25	107	120
9.50	63	182	24	149	173
12.00	74	225	29	113	125
13.50	89	303	39	52	18
15.00	96	319	53	32	35

10.58

2302

0014





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1110

4902

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0200

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1128

4002

0030

1130

1102

2300



4E00

2000

6E11

3





1140

1402

0036



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201E

1411



1148

201E

0400





1149

4502

2400

1150

4902

4400

1202

1702

9400

0400

201 E

E021



1204

5202

0050





13.14

22.02

4500



13.17

20.02

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13.18

3402

0050

1319

3902

0900



1320

4102

2900



13.36

15.02

0064





1337

2052

9900



13.38

27.02

0900





1339

4002

0070



1540

1302

0072



15.52

4202

0074





1554

0202

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1555

1302

0078







0829

5503

0104



9010

1303

0640

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2903

0110

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0845

1503

0114



0901

3103

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0902

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0122



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0957

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0146

0959

2103

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5903

1000



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0152



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2403

1010





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0156

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4.103

0.158

0910

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1038



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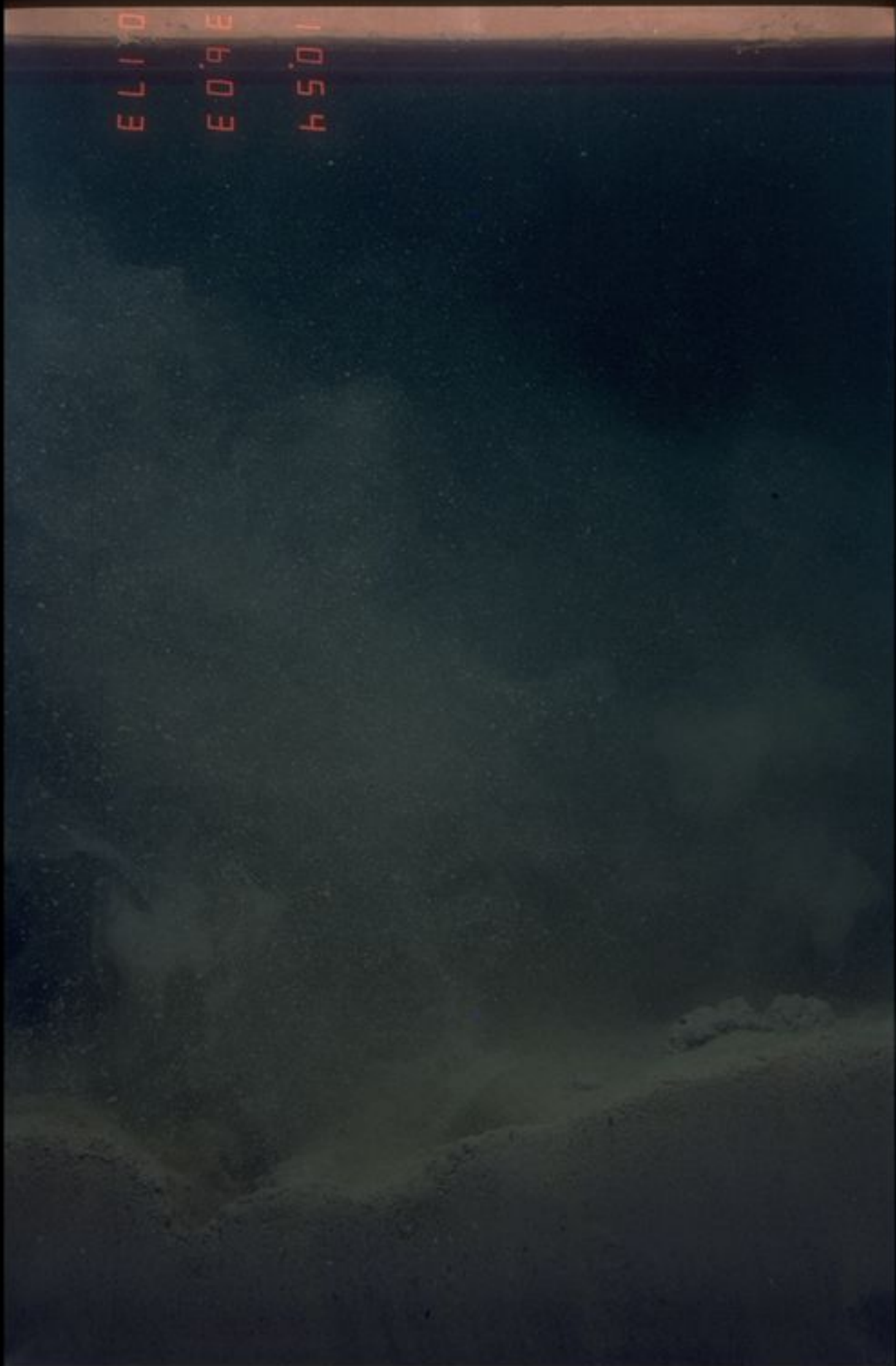
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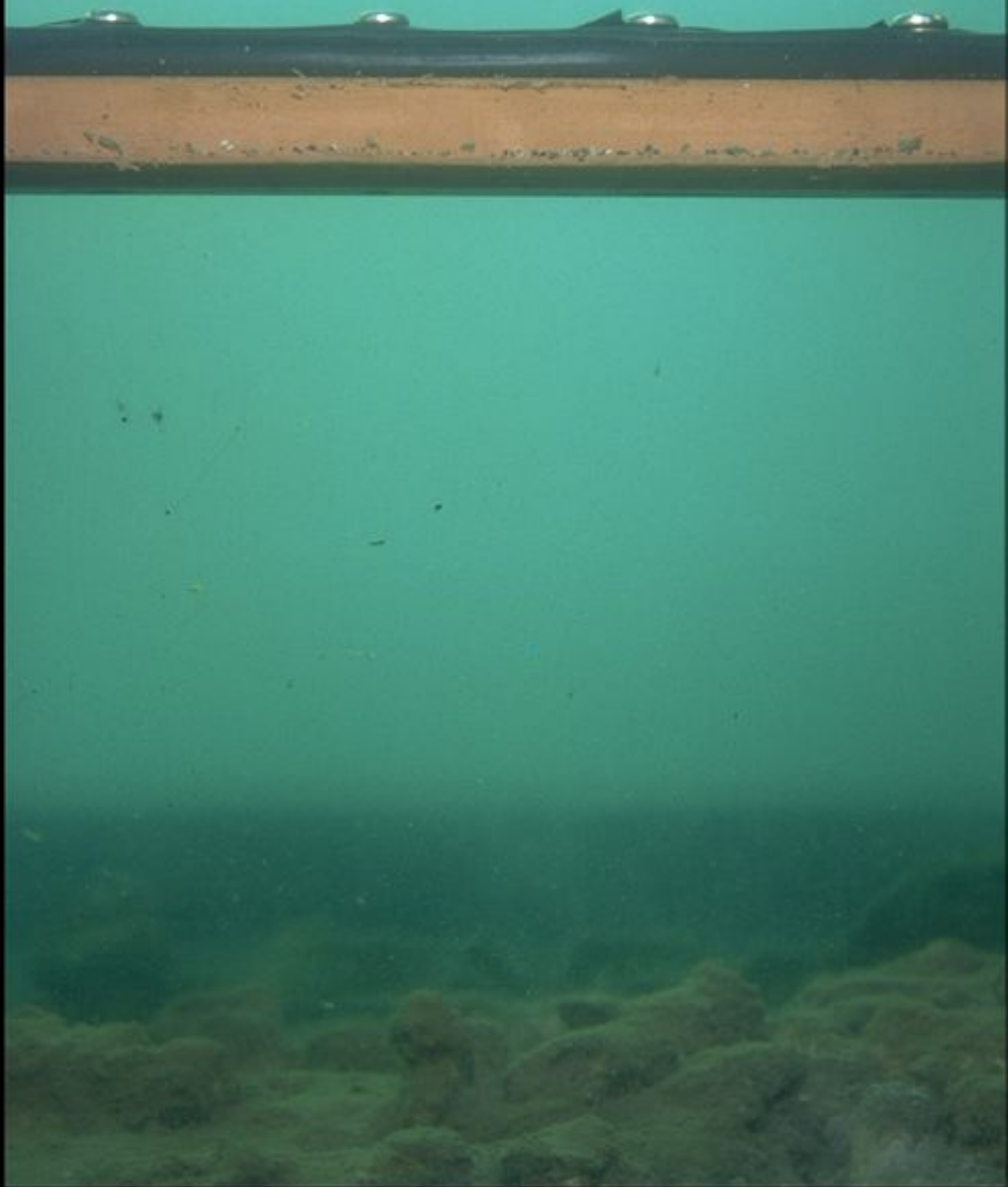
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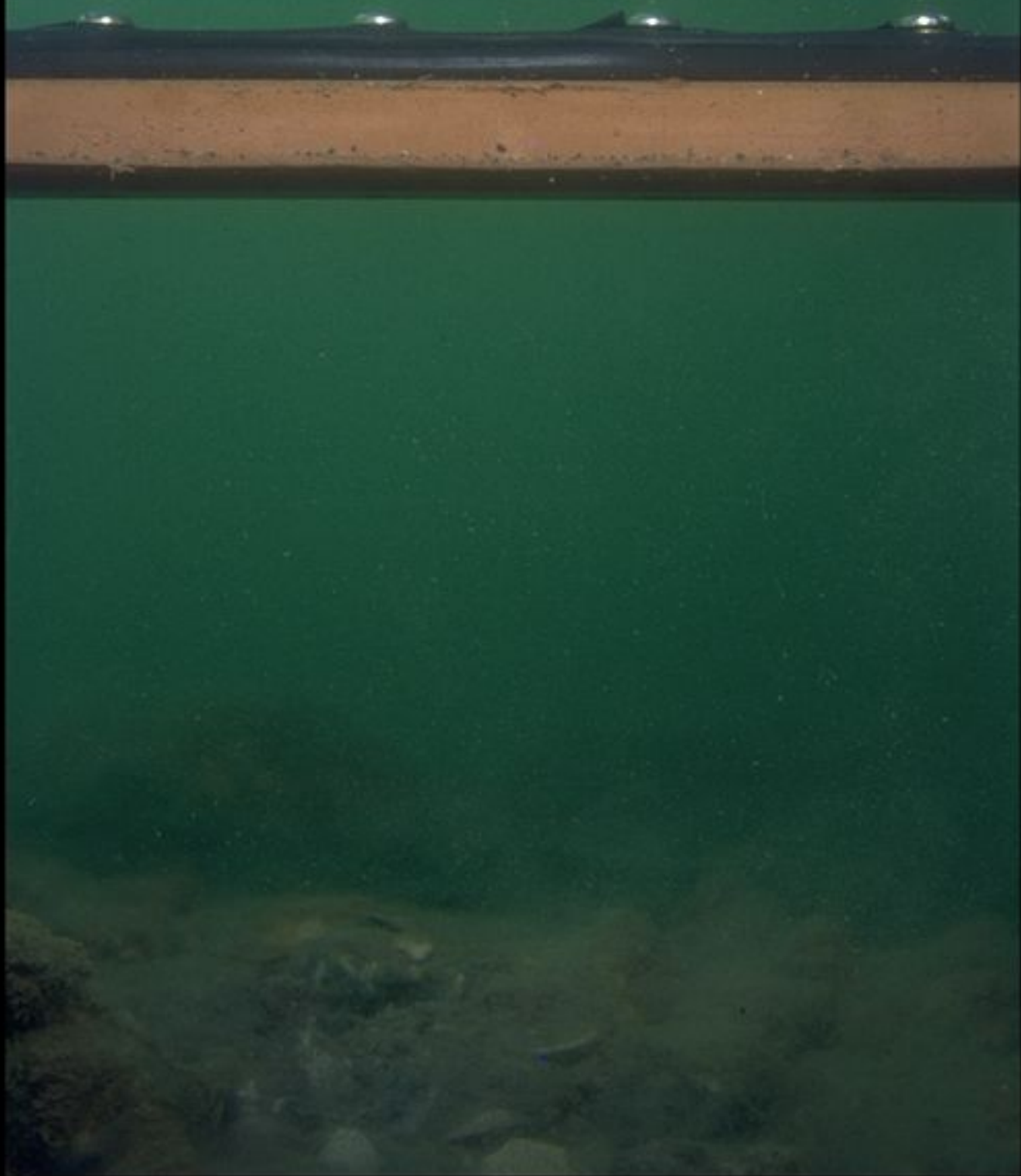
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1.203

1.154





5610

2103

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1201

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0197

1202  
5403  
0199

2020

1403

1204



4020

5503

6029

9020

9003

1213

0020

4603

1214



0120

2003

1216



InterOcean Systems, Inc. Model S4 Current Meter  
 SERIAL NUMBER : 04590867  
 HEADER : PRISM 2B  
 CYCLE : ON FOR 0 DAYS, 0 HR, 2 MIN  
 EVERY 0 DAYS, 0 HR, 4 MIN  
 AVERAGE COUNT : 240  
 CHANNELS AT AVERAGE : 2 3  
 TRUE AVERAGE : Disabled  
 SRB COUNT : 0  
 CHANNELS IN SRB : 1 2 3  
 FMT: 0  
 SENSITIVITIES : X = 256 Y = 256  
 OFFSETS : X = 1762 Y = 1760  
 BATTERY TYPE : A  
 DATE INSTALLED : 11/19/02  
 Sample Count : 560400  
 DATE OF DATA BLOCK : 12/16/02  
 TIME OF DATA BLOCK : 11:00  
 SAMPLES IN BLOCK : 7946  
 S4 VERSION : 2.24

InterOcean Systems, Inc. Model S4 Current Meter #04590867  
 PRISM 2 B File : BPCS4.S4B  
 Xoffset : +0.00 cm/s Yoffset: +0.00 cm/s Mag.Var.: 10 deg  
 Start: 12/16/02 11:00:00 End: 1/07/03 12:40:00 Samp: 1 to 7946

Date/Time

Speed (cm/s)	Dir (deg)	Hdg (deg)	Cond (mS/cm)	S-Temp (deg.C)	Depth (meters)	Tilt (deg)	Salin (psu)	Density (Kg/M <sup>3</sup> )	SV (M/s)
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12/16/2002 11:04	3.7	244	308						
12/16/2002 11:08	5.5	247	308						
12/16/2002 11:12	5.1	269	308						
12/16/2002 11:16	4.3	267	308						
12/16/2002 11:20	4.6	257	308						
12/16/2002 11:24	5.2	248	308						
12/16/2002 11:28	3.7	264	308						
12/16/2002 11:32	4	243	308						
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12/16/2002 11:44	4.1	237	309						
12/16/2002 11:48	4.8	238	308						
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12/16/2002 12:20	3	232	308						

12/16/2002 12:24	2.5	266	308
12/16/2002 12:28	2.1	231	308
12/16/2002 12:32	1.9	262	308
12/16/2002 12:36	2.5	309	308
12/16/2002 12:40	2.4	315	308
12/16/2002 12:44	2	286	308
12/16/2002 12:48	2.3	265	309
12/16/2002 12:52	3.2	280	308
12/16/2002 12:56	2.3	235	308
12/16/2002 13:00	2.1	219	308
12/16/2002 13:04	3.5	203	308
12/16/2002 13:08	2.9	206	308
12/16/2002 13:12	2.3	221	308
12/16/2002 13:16	2.2	224	308
12/16/2002 13:20	1.4	235	308
12/16/2002 13:24	1.2	271	308
12/16/2002 13:28	2	256	308
12/16/2002 13:32	2.8	272	308
12/16/2002 13:36	3.2	258	308
12/16/2002 13:40	4.5	259	308
12/16/2002 13:44	5.6	253	308
12/16/2002 13:48	5.9	252	308
12/16/2002 13:52	6.7	239	308
12/16/2002 13:56	6.7	243	308
12/16/2002 14:00	7.1	251	308
12/16/2002 14:04	6.1	242	308
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12/16/2002 14:12	4.7	240	310
12/16/2002 14:16	4.6	213	308
12/16/2002 14:20	3	227	308
12/16/2002 14:24	2.3	242	308
12/16/2002 14:28	2.3	242	308
12/16/2002 14:32	2.1	251	308
12/16/2002 14:36	3.3	237	308
12/16/2002 14:40	3.2	245	308
12/16/2002 14:44	3.6	242	308
12/16/2002 14:48	4	235	308
12/16/2002 14:52	3.5	221	308
12/16/2002 14:56	4	235	308
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12/16/2002 16:32	5.1	232	308
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12/16/2002 21:15	3	6	308
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12/16/2002 21:23	0.6	10	308
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12/16/2002 21:31	2	286	308
12/16/2002 21:35	3.7	258	308
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12/16/2002 21:47	4.7	226	308
12/16/2002 21:51	4.8	247	308
12/16/2002 21:55	4.5	239	308
12/16/2002 21:59	4.5	239	308
12/16/2002 22:03	4.7	244	308
12/16/2002 22:07	5.2	244	308
12/16/2002 22:11	5	257	308
12/16/2002 22:15	5.7	255	308
12/16/2002 22:19	6.3	263	308
12/16/2002 22:23	5.9	260	309
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12/16/2002 22:31	7.1	262	308



12/16/2002 22:35	8.1	260	309
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12/17/2002 1:35	4.9	268	308
12/17/2002 1:39	5.5	216	308
12/17/2002 1:43	8.5	223	308
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12/17/2002 1:51	9.8	221	309
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12/17/2002 1:59	7.4	231	308
12/17/2002 2:03	6.3	245	308
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1/6/2003 11:07	3.3	269	309
1/6/2003 11:11	3.5	233	309
1/6/2003 11:15	3.8	252	310
1/6/2003 11:19	4.7	226	310
1/6/2003 11:23	4.1	233	310
1/6/2003 11:27	4.8	232	310
1/6/2003 11:31	5.2	233	309

1/6/2003 11:35	4.8	232	309
1/6/2003 11:39	4	239	310
1/6/2003 11:43	4	235	310
1/6/2003 11:47	3.4	252	309
1/6/2003 11:51	3.9	250	309
1/6/2003 11:55	4.2	263	310
1/6/2003 11:59	4.1	251	309
1/6/2003 12:03	4.1	251	307
1/6/2003 12:07	3.8	248	309
1/6/2003 12:11	3.9	250	309
1/6/2003 12:15	4.2	249	310
1/6/2003 12:19	5.7	270	309
1/6/2003 12:23	5.4	265	309
1/6/2003 12:27	5.1	262	310
1/6/2003 12:31	5.1	262	309
1/6/2003 12:35	4.9	268	310
1/6/2003 12:39	5	264	310
1/6/2003 12:43	5.4	265	309
1/6/2003 12:47	4.6	280	309
1/6/2003 12:51	5	257	310
1/6/2003 12:55	4.1	233	310
1/6/2003 12:59	4.4	244	309
1/6/2003 13:03	4.8	258	310
1/6/2003 13:07	4.3	243	310
1/6/2003 13:11	5	237	310
1/6/2003 13:15	5.4	249	310
1/6/2003 13:19	5.6	242	309
1/6/2003 13:23	4.6	242	310
1/6/2003 13:27	3.6	246	310
1/6/2003 13:31	3.8	252	310
1/6/2003 13:35	4.3	246	309
1/6/2003 13:39	4.3	246	309
1/6/2003 13:43	4.8	247	310
1/6/2003 13:47	4.4	256	309
1/6/2003 13:51	4.6	242	309
1/6/2003 13:55	4.6	242	310
1/6/2003 13:59	4.8	238	309
1/6/2003 14:03	4.9	253	309
1/6/2003 14:07	4	253	310
1/6/2003 14:11	4.8	223	310
1/6/2003 14:15	8.3	197	309
1/6/2003 14:19	6.2	188	309
1/6/2003 14:23	2.3	205	309
1/6/2003 14:27	3.7	235	310
1/6/2003 14:31	4.2	207	310
1/6/2003 14:35	2.7	226	309
1/6/2003 14:39	3	238	309
1/6/2003 14:43	4.8	197	309
1/6/2003 14:47	3.9	205	310
1/6/2003 14:51	4.3	212	309
1/6/2003 14:55	3.5	200	310

1/6/2003 14:59	5.3	177	309
1/6/2003 15:03	4.4	185	310
1/6/2003 15:07	4.4	187	309
1/6/2003 15:11	2.2	200	309
1/6/2003 15:15	3	227	310
1/6/2003 15:19	4.7	233	310
1/6/2003 15:23	5.8	242	310
1/6/2003 15:27	6.4	254	310
1/6/2003 15:31	7.3	264	309
1/6/2003 15:35	5.6	280	309
1/6/2003 15:39	4.1	269	310
1/6/2003 15:43	4	277	310
1/6/2003 15:47	2.8	284	309
1/6/2003 15:51	3.5	270	309
1/6/2003 15:55	2.3	332	309
1/6/2003 15:59	1.6	356	310
1/6/2003 16:03	1.6	340	310
1/6/2003 16:07	2.2	5	309
1/6/2003 16:11	0.8	24	309
1/6/2003 16:15	0.4	253	309
1/6/2003 16:19	0.7	66	309
1/6/2003 16:23	1.4	18	310
1/6/2003 16:27	2.8	2	310
1/6/2003 16:31	2.5	28	309
1/6/2003 16:35	2.8	10	310
1/6/2003 16:39	2	359	307
1/6/2003 16:43	5	5	309
1/6/2003 16:47	4.7	0	309
1/6/2003 16:51	1.8	10	309
1/6/2003 16:55	3.8	352	310
1/6/2003 16:59	3.4	353	310
1/6/2003 17:03	1.7	349	309
1/6/2003 17:07	2.1	353	310
1/6/2003 17:11	0.6	10	309
1/6/2003 17:15	1.2	10	309
1/6/2003 17:19	0.2	280	309
1/6/2003 17:23	4.7	292	309
1/6/2003 17:27	5.4	280	310
1/6/2003 17:31	5.8	264	310
1/6/2003 17:35	6.5	269	309
1/6/2003 17:39	6.9	250	309
1/6/2003 17:43	5.8	246	309
1/6/2003 17:47	4.7	268	309
1/6/2003 17:51	5.3	267	309
1/6/2003 17:55	5.2	252	310
1/6/2003 17:59	5.3	243	309
1/6/2003 18:03	5.1	241	309
1/6/2003 18:07	4.7	244	309
1/6/2003 18:11	3.8	252	310
1/6/2003 18:15	3.7	226	309
1/6/2003 18:19	3.8	252	310

1/6/2003 18:23	2.9	255	309
1/6/2003 18:27	3.2	245	310
1/6/2003 18:31	2.1	251	309
1/6/2003 18:35	1.1	258	309
1/6/2003 18:39	0.9	307	309
1/6/2003 18:43	2	359	309
1/6/2003 18:47	1.4	336	309
1/6/2003 18:51	0.9	343	309
1/6/2003 18:55	1.7	325	309
1/6/2003 18:59	1.8	274	309
1/6/2003 19:03	4.4	256	309
1/6/2003 19:07	5.1	262	309
1/6/2003 19:11	4.6	262	309
1/6/2003 19:15	4	262	309
1/6/2003 19:19	3.5	249	309
1/6/2003 19:23	3.3	237	309
1/6/2003 19:27	2.2	246	309
1/6/2003 19:31	2.7	263	309
1/6/2003 19:35	2.3	260	309
1/6/2003 19:39	2.9	255	309
1/6/2003 19:43	3.5	270	309
1/6/2003 19:47	3.6	271	309
1/6/2003 19:51	3.8	262	309
1/6/2003 19:55	4.1	266	309
1/6/2003 19:59	3.8	255	309
1/6/2003 20:03	3.8	241	309
1/6/2003 20:07	3.7	244	309
1/6/2003 20:11	4.2	255	309
1/6/2003 20:15	4.5	253	309
1/6/2003 20:19	4.3	258	309
1/6/2003 20:23	4.5	248	309
1/6/2003 20:27	3.7	244	309
1/6/2003 20:31	4.2	235	309
1/6/2003 20:35	3.3	228	309
1/6/2003 20:39	4	243	309
1/6/2003 20:43	4.4	262	309
1/6/2003 20:47	4.6	251	309
1/6/2003 20:51	4.7	255	307
1/6/2003 20:55	4.8	256	309
1/6/2003 20:59	5.7	268	309
1/6/2003 21:03	6	266	309
1/6/2003 21:07	5.5	267	309
1/6/2003 21:11	5.2	273	309
1/6/2003 21:15	2.4	271	309
1/6/2003 21:19	3.5	267	309
1/6/2003 21:23	3.9	256	309
1/6/2003 21:27	3.4	259	309
1/6/2003 21:31	4.5	253	309
1/6/2003 21:35	5.9	252	309
1/6/2003 21:39	5.7	262	309
1/6/2003 21:43	4.6	278	309

1/6/2003 21:47	4.7	270	309
1/6/2003 21:51	4.2	255	309
1/6/2003 21:55	3.1	240	309
1/6/2003 21:59	4.1	257	309
1/6/2003 22:03	5.4	263	309
1/6/2003 22:07	5.3	255	309
1/6/2003 22:11	4.9	248	309
1/6/2003 22:15	4.7	252	309
1/6/2003 22:19	4.8	258	309
1/6/2003 22:23	4.2	261	309
1/6/2003 22:27	4.2	255	309
1/6/2003 22:31	4.8	256	309
1/6/2003 22:35	5.4	258	309
1/6/2003 22:39	4.9	253	309
1/6/2003 22:43	4.9	261	309
1/6/2003 22:47	4.2	255	309
1/6/2003 22:51	4.3	243	309
1/6/2003 22:55	4	253	309
1/6/2003 22:59	4.3	258	309
1/6/2003 23:03	3.5	249	308
1/6/2003 23:07	3.9	265	309
1/6/2003 23:11	3.4	259	309
1/6/2003 23:15	4	253	309
1/6/2003 23:19	3.7	267	309
1/6/2003 23:23	3.8	277	309
1/6/2003 23:27	4	262	309
1/6/2003 23:31	3.8	280	309
1/6/2003 23:35	4.3	258	309
1/6/2003 23:39	4.4	250	309
1/6/2003 23:43	4	247	309
1/6/2003 23:47	4.3	252	309
1/6/2003 23:51	4.8	250	309
1/6/2003 23:55	5.2	252	309
1/6/2003 23:59	5.2	252	309
1/7/2003 0:03	5.6	263	309
1/7/2003 0:07	5.3	251	309
1/7/2003 0:11	4.5	259	309
1/7/2003 0:15	4.5	259	309
1/7/2003 0:19	5.6	259	309
1/7/2003 0:23	5.7	262	309
1/7/2003 0:27	4.7	252	309
1/7/2003 0:31	4.4	237	309
1/7/2003 0:35	4.9	248	309
1/7/2003 0:39	5.5	247	309
1/7/2003 0:43	5.8	253	309
1/7/2003 0:47	5.6	257	309
1/7/2003 0:51	5.6	259	309
1/7/2003 0:55	4.9	253	309
1/7/2003 0:59	4.8	258	309
1/7/2003 1:03	5.6	259	309
1/7/2003 1:07	5.7	255	309

1/7/2003 1:11	5	251	309
1/7/2003 1:15	4.8	247	309
1/7/2003 1:19	1.8	293	309
1/7/2003 1:23	2.3	350	309
1/7/2003 1:27	2.3	350	309
1/7/2003 1:31	2.8	10	309
1/7/2003 1:35	2	10	309
1/7/2003 1:39	3.1	359	309
1/7/2003 1:43	3.1	265	309
1/7/2003 1:47	3.7	264	309
1/7/2003 1:51	4.7	260	309
1/7/2003 1:55	5.8	260	309
1/7/2003 1:59	4.6	257	309
1/7/2003 2:03	4.5	259	309
1/7/2003 2:07	4.1	257	309
1/7/2003 2:11	4.2	275	309
1/7/2003 2:15	3.9	259	309
1/7/2003 2:19	3.5	264	309
1/7/2003 2:23	2.3	249	309
1/7/2003 2:27	2.8	272	309
1/7/2003 2:31	3	280	309
1/7/2003 2:35	2.8	259	309
1/7/2003 2:39	2.6	280	309
1/7/2003 2:43	2.2	285	309
1/7/2003 2:47	2.2	280	309
1/7/2003 2:51	2.4	280	309
1/7/2003 2:55	1.9	262	309
1/7/2003 2:59	1.8	253	309
1/7/2003 3:03	1.8	253	309
1/7/2003 3:07	2.6	276	309
1/7/2003 3:11	3	276	309
1/7/2003 3:15	4.1	266	309
1/7/2003 3:19	4.3	267	309
1/7/2003 3:23	3.9	265	309
1/7/2003 3:27	3.4	283	309
1/7/2003 3:31	3.6	280	309
1/7/2003 3:35	3.1	265	309
1/7/2003 3:39	3	280	309
1/7/2003 3:43	2.8	276	309
1/7/2003 3:47	2.6	280	309
1/7/2003 3:51	2.5	266	309
1/7/2003 3:55	2.2	280	309
1/7/2003 3:59	2.5	266	309
1/7/2003 4:03	2.8	280	309
1/7/2003 4:07	2	256	309
1/7/2003 4:11	1.9	262	309
1/7/2003 4:15	2.4	275	309
1/7/2003 4:19	2.4	280	309
1/7/2003 4:23	4	280	309
1/7/2003 4:27	4.2	261	309
1/7/2003 4:31	3.9	268	309

1/7/2003 4:35	5.3	271	309
1/7/2003 4:39	5.2	273	307
1/7/2003 4:43	4.8	263	309
1/7/2003 4:47	4.2	272	310
1/7/2003 4:51	4.4	272	309
1/7/2003 4:55	5.2	276	309
1/7/2003 4:59	5.5	272	309
1/7/2003 5:03	4.8	263	309
1/7/2003 5:07	4.6	262	309
1/7/2003 5:11	3.9	265	309
1/7/2003 5:15	3.6	277	309
1/7/2003 5:19	4	271	309
1/7/2003 5:23	3.7	251	309
1/7/2003 5:27	3.8	255	309
1/7/2003 5:31	3.6	271	309
1/7/2003 5:35	4.1	251	309
1/7/2003 5:39	3.7	264	309
1/7/2003 5:43	3.1	269	309
1/7/2003 5:47	2.9	255	310
1/7/2003 5:51	2.6	248	309
1/7/2003 5:55	2.2	280	310
1/7/2003 5:59	1.6	230	309
1/7/2003 6:03	1.8	321	309
1/7/2003 6:07	1.3	307	310
1/7/2003 6:11	1.8	267	309
1/7/2003 6:15	4.8	275	309
1/7/2003 6:19	4.2	272	309
1/7/2003 6:23	4.4	285	310
1/7/2003 6:27	5.5	288	309
1/7/2003 6:31	5.7	288	309
1/7/2003 6:35	5.5	272	309
1/7/2003 6:39	5.2	264	310
1/7/2003 6:43	5.2	257	309
1/7/2003 6:47	5.1	271	309
1/7/2003 6:51	4.4	264	310
1/7/2003 6:55	5.4	276	309
1/7/2003 6:59	4.6	273	309
1/7/2003 7:03	3.5	256	309
1/7/2003 7:07	3.4	263	309
1/7/2003 7:11	4	280	309
1/7/2003 7:15	4	271	309
1/7/2003 7:19	3.6	271	310
1/7/2003 7:23	3.7	267	310
1/7/2003 7:27	3.2	280	309
1/7/2003 7:31	3	280	309
1/7/2003 7:35	3.3	242	310
1/7/2003 7:39	1.7	259	310
1/7/2003 7:43	2.2	224	309
1/7/2003 7:47	2.1	239	309
1/7/2003 7:51	2.6	241	310
1/7/2003 7:55	2.5	235	310

1/7/2003 7:59	2.6	229	309
1/7/2003 8:03	3.3	233	309
1/7/2003 8:07	3.9	250	309
1/7/2003 8:11	5.8	253	309
1/7/2003 8:15	6.7	263	309
1/7/2003 8:19	6.8	266	310
1/7/2003 8:23	5.7	262	309
1/7/2003 8:27	7.1	272	309
1/7/2003 8:31	5.4	258	309
1/7/2003 8:35	4.5	259	309
1/7/2003 8:39	3.6	253	309
1/7/2003 8:43	3.7	235	309
1/7/2003 8:47	4.6	246	309
1/7/2003 8:51	4.4	264	309
1/7/2003 8:55	5	257	309
1/7/2003 8:59	5.1	271	309
1/7/2003 9:03	3.8	289	309
1/7/2003 9:07	3.8	274	309
1/7/2003 9:11	3.2	262	309
1/7/2003 9:15	2.6	229	309
1/7/2003 9:19	2.6	248	309
1/7/2003 9:23	2.7	253	309
1/7/2003 9:27	3.3	233	309
1/7/2003 9:31	4	247	310
1/7/2003 9:35	4.5	259	310
1/7/2003 9:39	4.4	250	309
1/7/2003 9:43	4.5	270	309
1/7/2003 9:47	3.2	284	309
1/7/2003 9:51	4	262	310
1/7/2003 9:55	4	253	309
1/7/2003 9:59	5.4	253	309
1/7/2003 10:03	4.8	247	309
1/7/2003 10:07	4.8	247	309
1/7/2003 10:11	5.4	258	309
1/7/2003 10:15	4.4	250	310
1/7/2003 10:19	4.9	245	309
1/7/2003 10:23	6.3	253	309
1/7/2003 10:27	6.6	260	309
1/7/2003 10:31	6.3	253	309
1/7/2003 10:35	6.9	263	309
1/7/2003 10:39	5.9	270	310
1/7/2003 10:43	4.2	263	310
1/7/2003 10:47	3.3	228	310
1/7/2003 10:51	3.2	250	310
1/7/2003 10:55	9.9	288	43
1/7/2003 10:59	5.5	76	276
1/7/2003 11:03	7.8	312	216
1/7/2003 11:07	10.9	154	55
1/7/2003 11:11	12.8	241	145
1/7/2003 11:15	12.7	302	145
1/7/2003 11:19	82.3	241	64



1/7/2003 11:23	47.4	338	162
1/7/2003 11:27	17.8	22	162
1/7/2003 11:31	20.7	17	162
1/7/2003 11:35	27.2	7	162
1/7/2003 11:39	12.1	109	162
1/7/2003 11:43	14.8	126	163
1/7/2003 11:47	27.9	6	162
1/7/2003 11:51	47.2	357	162
1/7/2003 11:55	66.6	353	162
1/7/2003 11:59	52.7	151	163
1/7/2003 12:03	59.6	354	163
1/7/2003 12:07	71	156	162
1/7/2003 12:11	53.6	357	163
1/7/2003 12:15	43.2	2	163
1/7/2003 12:19	63.5	157	163
1/7/2003 12:23	42.6	4	163
1/7/2003 12:27	29	146	101
1/7/2003 12:31	26.3	77	102
1/7/2003 12:35	3.3	57	111
1/7/2003 12:39	3	170	110

InterOcean Systems, Inc. Model S4 Current Meter  
 SERIAL NUMBER : 05451203  
 HEADER : PRISM 2B  
 CYCLE : ON FOR 0 DAYS, 0 HR, 2 MIN  
 EVERY 0 DAYS, 0 HR, 4 MIN  
 AVERAGE COUNT : 240  
 CHANNELS AT AVERAGE : 2 3  
 TRUE AVERAGE : Disabled  
 SRB COUNT : 0  
 CHANNELS IN SRB : 1 2 3  
 FMT: 0  
 SENSITIVITIES : X = 234 Y = 236  
 OFFSETS : X = 1744 Y = 1765  
 BATTERY TYPE : A  
 DATE INSTALLED : 12/13/02  
 Sample Count : 0  
 DATE OF DATA BLOCK : 12/14/02  
 TIME OF DATA BLOCK : 16:00  
 SAMPLES IN BLOCK : 8666  
 S4 VERSION : 2.39

InterOcean Systems, Inc. Model S4 Current Meter #05451203  
 PRISM 2B File : SLCS4.S4B  
 Xoffset : +0.00 cm/s Yoffset: +0.00 cm/s Mag.Var.: 10 deg  
 Start: 12/14/02 16:00:00 End: 1/07/03 17:40:00 Samp: 1 to 8666

Date/Time	Speed (cm/s)	Dir (deg)	Hdg (deg)	Cond (mS/cm)	S-Temp (deg.C)	Depth (meters)	Tilt (deg)	Salin (psu)	Density (Kg/M^3)	SV (M/s)
12/14/2002 16:00	0.9	355		260						
12/14/2002 16:04	0.9	355		260						
12/14/2002 16:08	1	353		260						
12/14/2002 16:12	0.9	347		260						
12/14/2002 16:16	0.7	347		260						
12/14/2002 16:20	0.6	360		260						
12/14/2002 16:24	1	3		260						
12/14/2002 16:28	1	7		260						
12/14/2002 16:32	0.8	10		260						
12/14/2002 16:36	0.9	10		260						
12/14/2002 16:40	0.9	6		260						
12/14/2002 16:44	0.6	10		260						
12/14/2002 16:48	0.8	1		260						
12/14/2002 16:52	0.9	3		260						
12/14/2002 16:56	0.8	19		260						
12/14/2002 17:00	0.8	2		260						
12/14/2002 17:04	0.9	10		260						
12/14/2002 17:08	0.9	6		260						
12/14/2002 17:12	0.9	6		260						
12/14/2002 17:16	0.7	6		260						
12/14/2002 17:20	0.6	359		260						
12/14/2002 17:24	0.6	359		260						

12/14/2002 17:28	0.7	356	260
12/14/2002 17:32	0.8	2	260
12/14/2002 17:36	0.7	10	260
12/14/2002 17:40	1	27	260
12/14/2002 17:44	0.9	35	260
12/14/2002 17:48	0.6	21	260
12/14/2002 17:52	0.7	5	260
12/14/2002 17:56	0.8	31	260
12/14/2002 18:00	0.9	21	260
12/14/2002 18:04	0.7	10	260
12/14/2002 18:08	0.5	10	260
12/14/2002 18:12	0.8	2	260
12/14/2002 18:16	0.7	19	260
12/14/2002 18:20	0.9	10	260
12/14/2002 18:24	0.8	18	260
12/14/2002 18:28	0.7	34	260
12/14/2002 18:32	0.8	22	260
12/14/2002 18:36	0.7	28	260
12/14/2002 18:40	0.7	5	260
12/14/2002 18:44	0.9	21	260
12/14/2002 18:48	0.9	10	260
12/14/2002 18:52	1	17	260
12/14/2002 18:56	1	10	260
12/14/2002 19:00	0.6	16	260
12/14/2002 19:04	1	4	260
12/14/2002 19:08	0.9	18	260
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12/18/2002 10:20	0.8	358	260
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12/18/2002 15:28	0.9	2	260
12/18/2002 15:32	0.9	2	260
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12/18/2002 15:40	0.8	2	260
12/18/2002 15:44	0.9	2	260
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12/18/2002 15:52	1	7	260
12/18/2002 15:56	1	3	260
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12/18/2002 16:16	0.7	350	260
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12/18/2002 16:24	0.8	1	260
12/18/2002 16:28	0.8	357	260
12/18/2002 16:32	0.8	357	260
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12/18/2002 17:56	0.8	350	260
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12/18/2002 18:56	1	351	260
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12/19/2002 22:52	0.9	21	260
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12/20/2002 17:56	0.8	357	260
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12/24/2002 16:32	0.8	1	260
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12/27/2002 10:56	0.8	349	260
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12/27/2002 11:16	0.8	345	260
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12/27/2002 11:24	0.8	350	260

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12/27/2002 12:08	0.7	1	260
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12/27/2002 12:16	0.8	2	260
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12/27/2002 18:52	0.9	3	260
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12/27/2002 19:32	0.9	14	260
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12/27/2002 21:32	0.8	2	260
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12/27/2002 21:52	0.9	355	260
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1/6/2003 14:28	1	20	260
1/6/2003 14:32	0.9	21	260
1/6/2003 14:36	0.9	17	260
1/6/2003 14:40	1	20	260
1/6/2003 14:44	0.9	18	260
1/6/2003 14:48	0.9	21	260
1/6/2003 14:52	1	27	260
1/6/2003 14:56	0.9	10	260
1/6/2003 15:00	0.7	10	260
1/6/2003 15:04	0.7	5	260
1/6/2003 15:08	0.6	10	260
1/6/2003 15:12	0.8	10	260
1/6/2003 15:16	0.9	28	260
1/6/2003 15:20	0.9	21	260
1/6/2003 15:24	1.1	16	260
1/6/2003 15:28	1	7	260
1/6/2003 15:32	1	7	260
1/6/2003 15:36	0.9	352	260
1/6/2003 15:40	0.8	350	260
1/6/2003 15:44	1	349	260
1/6/2003 15:48	1	349	260
1/6/2003 15:52	1	343	260
1/6/2003 15:56	0.9	345	260
1/6/2003 16:00	1.1	334	260
1/6/2003 16:04	0.9	348	260
1/6/2003 16:08	1.1	348	260
1/6/2003 16:12	1.1	343	260

1/6/2003 16:16	0.9	343	260
1/6/2003 16:20	1.1	346	260
1/6/2003 16:24	0.8	342	260
1/6/2003 16:28	0.9	6	260
1/6/2003 16:32	0.7	19	260
1/6/2003 16:36	0.8	19	260
1/6/2003 16:40	1.2	21	260
1/6/2003 16:44	0.7	24	260
1/6/2003 16:48	1	27	260
1/6/2003 16:52	0.6	20	260
1/6/2003 16:56	1	39	260
1/6/2003 17:00	0.8	18	260
1/6/2003 17:04	0.8	19	260
1/6/2003 17:08	0.7	24	260
1/6/2003 17:12	0.8	10	260
1/6/2003 17:16	1	26	260
1/6/2003 17:20	0.9	25	260
1/6/2003 17:24	1	29	260
1/6/2003 17:28	0.9	25	260
1/6/2003 17:32	0.8	30	260
1/6/2003 17:36	1	26	260
1/6/2003 17:40	0.8	18	260
1/6/2003 17:44	0.7	10	260
1/6/2003 17:48	0.9	18	260
1/6/2003 17:52	0.9	21	260
1/6/2003 17:56	0.9	17	260
1/6/2003 18:00	0.9	21	260
1/6/2003 18:04	0.9	17	260
1/6/2003 18:08	0.9	14	260
1/6/2003 18:12	0.9	14	260
1/6/2003 18:16	0.9	21	260
1/6/2003 18:20	0.9	18	260
1/6/2003 18:24	0.9	14	260
1/6/2003 18:28	0.9	10	260
1/6/2003 18:32	0.8	6	260
1/6/2003 18:36	0.8	10	260
1/6/2003 18:40	0.9	6	260
1/6/2003 18:44	1	360	260
1/6/2003 18:48	1	3	260
1/6/2003 18:52	1.1	354	260
1/6/2003 18:56	1.2	353	260
1/6/2003 19:00	0.9	356	260
1/6/2003 19:04	1	360	260
1/6/2003 19:08	1	357	260
1/6/2003 19:12	0.9	3	260
1/6/2003 19:16	0.9	359	260
1/6/2003 19:20	0.9	359	260
1/6/2003 19:24	0.8	2	260
1/6/2003 19:28	1	1	260
1/6/2003 19:32	0.8	358	260
1/6/2003 19:36	1	360	260

1/6/2003 19:40	0.9	359	260
1/6/2003 19:44	0.8	6	260
1/6/2003 19:48	0.9	6	260
1/6/2003 19:52	1	7	260
1/6/2003 19:56	0.8	6	260
1/6/2003 20:00	0.9	2	260
1/6/2003 20:04	0.8	2	260
1/6/2003 20:08	1	3	260
1/6/2003 20:12	0.9	6	260
1/6/2003 20:16	1	360	260
1/6/2003 20:20	0.8	358	260
1/6/2003 20:24	0.9	356	260
1/6/2003 20:28	0.8	349	260
1/6/2003 20:32	0.9	3	260
1/6/2003 20:36	0.9	356	260
1/6/2003 20:40	1	353	260
1/6/2003 20:44	1	346	260
1/6/2003 20:48	1	346	260
1/6/2003 20:52	1	341	260
1/6/2003 20:56	1.1	338	260
1/6/2003 21:00	1.1	345	260
1/6/2003 21:04	1.1	348	260
1/6/2003 21:08	1	346	260
1/6/2003 21:12	1.1	338	260
1/6/2003 21:16	1	342	260
1/6/2003 21:20	1	351	260
1/6/2003 21:24	1.1	358	260
1/6/2003 21:28	1.1	352	260
1/6/2003 21:32	1	351	260
1/6/2003 21:36	0.9	348	260
1/6/2003 21:40	1	349	260
1/6/2003 21:44	0.9	356	259
1/6/2003 21:48	1	349	260
1/6/2003 21:52	0.9	359	260
1/6/2003 21:56	0.9	2	260
1/6/2003 22:00	0.9	3	260
1/6/2003 22:04	0.9	359	260
1/6/2003 22:08	1	360	260
1/6/2003 22:12	1	360	260
1/6/2003 22:16	0.9	359	260
1/6/2003 22:20	0.8	353	260
1/6/2003 22:24	0.9	352	260
1/6/2003 22:28	0.9	352	260
1/6/2003 22:32	0.9	352	260
1/6/2003 22:36	1	353	260
1/6/2003 22:40	1	357	260
1/6/2003 22:44	1	357	260
1/6/2003 22:48	1	354	260
1/6/2003 22:52	1	360	260
1/6/2003 22:56	1	3	260
1/6/2003 23:00	1	4	260

1/6/2003 23:04	1	3	260
1/6/2003 23:08	1	3	260
1/6/2003 23:12	0.9	6	260
1/6/2003 23:16	0.9	359	260
1/6/2003 23:20	1	3	260
1/6/2003 23:24	0.9	356	260
1/6/2003 23:28	0.9	2	260
1/6/2003 23:32	0.9	3	260
1/6/2003 23:36	0.9	6	260
1/6/2003 23:40	0.8	6	260
1/6/2003 23:44	0.7	6	260
1/6/2003 23:48	0.8	6	260
1/6/2003 23:52	0.7	1	260
1/6/2003 23:56	0.8	6	260
1/7/2003 0:00	0.7	1	260
1/7/2003 0:04	0.7	6	260
1/7/2003 0:08	0.7	1	260
1/7/2003 0:12	0.7	6	260
1/7/2003 0:16	0.8	1	260
1/7/2003 0:20	0.7	1	260
1/7/2003 0:24	0.7	6	260
1/7/2003 0:28	0.7	6	260
1/7/2003 0:32	0.9	10	260
1/7/2003 0:36	0.9	2	260
1/7/2003 0:40	0.9	6	260
1/7/2003 0:44	0.9	2	259
1/7/2003 0:48	0.8	358	260
1/7/2003 0:52	0.9	359	260
1/7/2003 0:56	0.8	358	260
1/7/2003 1:00	0.8	2	260
1/7/2003 1:04	0.9	6	260
1/7/2003 1:08	0.9	10	260
1/7/2003 1:12	0.9	10	260
1/7/2003 1:16	0.9	6	260
1/7/2003 1:20	0.7	10	260
1/7/2003 1:24	0.8	1	260
1/7/2003 1:28	0.8	2	260
1/7/2003 1:32	0.8	6	260
1/7/2003 1:36	0.8	2	260
1/7/2003 1:40	0.8	6	260
1/7/2003 1:44	0.8	6	260
1/7/2003 1:48	0.9	6	260
1/7/2003 1:52	0.9	10	260
1/7/2003 1:56	0.8	10	260
1/7/2003 2:00	0.8	6	260
1/7/2003 2:04	0.7	10	260
1/7/2003 2:08	0.7	6	260
1/7/2003 2:12	0.7	1	260
1/7/2003 2:16	0.7	5	260
1/7/2003 2:20	0.7	6	260
1/7/2003 2:24	0.8	10	260

1/7/2003 2:28	0.9	10	260
1/7/2003 2:32	0.9	6	260
1/7/2003 2:36	0.9	6	260
1/7/2003 2:40	0.9	6	260
1/7/2003 2:44	0.9	10	260
1/7/2003 2:48	0.9	10	260
1/7/2003 2:52	0.9	10	260
1/7/2003 2:56	0.9	14	260
1/7/2003 3:00	0.9	21	260
1/7/2003 3:04	0.9	21	260
1/7/2003 3:08	0.9	21	260
1/7/2003 3:12	0.9	21	260
1/7/2003 3:16	0.9	21	260
1/7/2003 3:20	0.9	25	260
1/7/2003 3:24	0.9	28	260
1/7/2003 3:28	0.9	25	260
1/7/2003 3:32	1	27	260
1/7/2003 3:36	0.9	25	260
1/7/2003 3:40	0.9	28	260
1/7/2003 3:44	0.8	30	260
1/7/2003 3:48	0.8	27	260
1/7/2003 3:52	0.8	26	260
1/7/2003 3:56	0.8	26	260
1/7/2003 4:00	0.8	26	260
1/7/2003 4:04	0.9	33	260
1/7/2003 4:08	0.9	28	260
1/7/2003 4:12	0.9	33	260
1/7/2003 4:16	0.9	28	260
1/7/2003 4:20	0.9	25	260
1/7/2003 4:24	0.8	22	260
1/7/2003 4:28	0.9	25	260
1/7/2003 4:32	0.9	25	260
1/7/2003 4:36	0.9	25	260
1/7/2003 4:40	0.9	24	260
1/7/2003 4:44	0.9	28	260
1/7/2003 4:48	1	27	260
1/7/2003 4:52	0.9	28	260
1/7/2003 4:56	0.9	24	260
1/7/2003 5:00	0.9	25	260
1/7/2003 5:04	0.9	21	260
1/7/2003 5:08	0.8	18	260
1/7/2003 5:12	0.8	14	260
1/7/2003 5:16	0.8	18	260
1/7/2003 5:20	0.8	14	260
1/7/2003 5:24	0.8	14	260
1/7/2003 5:28	0.7	14	260
1/7/2003 5:32	0.8	19	260
1/7/2003 5:36	0.8	18	260
1/7/2003 5:40	0.8	14	260
1/7/2003 5:44	0.8	10	260
1/7/2003 5:48	0.8	10	260



1/7/2003 5:52	0.8	10	260
1/7/2003 5:56	0.8	10	260
1/7/2003 6:00	0.7	6	260
1/7/2003 6:04	0.7	6	260
1/7/2003 6:08	0.8	1	260
1/7/2003 6:12	0.7	6	260
1/7/2003 6:16	0.7	1	260
1/7/2003 6:20	0.8	358	260
1/7/2003 6:24	0.8	2	260
1/7/2003 6:28	0.9	359	260
1/7/2003 6:32	0.8	2	260
1/7/2003 6:36	0.7	5	260
1/7/2003 6:40	0.6	4	260
1/7/2003 6:44	1	10	260
1/7/2003 6:48	0.9	6	260
1/7/2003 6:52	0.6	10	260
1/7/2003 6:56	1	13	260
1/7/2003 7:00	0.8	22	260
1/7/2003 7:04	0.7	1	260
1/7/2003 7:08	0.8	1	260
1/7/2003 7:12	0.8	6	260
1/7/2003 7:16	0.9	3	260
1/7/2003 7:20	0.7	10	260
1/7/2003 7:24	0.8	350	260
1/7/2003 7:28	0.8	14	260
1/7/2003 7:32	0.9	6	260
1/7/2003 7:36	0.9	14	260
1/7/2003 7:40	0.9	6	260
1/7/2003 7:44	0.6	5	260
1/7/2003 7:48	0.9	6	260
1/7/2003 7:52	0.9	10	260
1/7/2003 7:56	1	34	260
1/7/2003 8:00	1.4	32	260
1/7/2003 8:04	0.8	6	260
1/7/2003 8:08	0.7	10	260
1/7/2003 8:12	1	10	260
1/7/2003 8:16	1	13	260
1/7/2003 8:20	0.8	6	260
1/7/2003 8:24	0.6	359	260
1/7/2003 8:28	1	10	260
1/7/2003 8:32	0.9	24	260
1/7/2003 8:36	1.1	13	260
1/7/2003 8:40	0.7	34	260
1/7/2003 8:44	0.7	10	260
1/7/2003 8:48	0.4	18	260
1/7/2003 8:52	1.1	7	260
1/7/2003 8:56	1	20	260
1/7/2003 9:00	0.9	6	260
1/7/2003 9:04	0.7	1	260
1/7/2003 9:08	1	351	260
1/7/2003 9:12	0.6	360	260

1/7/2003 9:16	0.8	357	260
1/7/2003 9:20	0.9	10	260
1/7/2003 9:24	0.7	1	260
1/7/2003 9:28	0.7	356	260
1/7/2003 9:32	0.8	10	260
1/7/2003 9:36	1	10	260
1/7/2003 9:40	0.9	14	260
1/7/2003 9:44	0.9	14	260
1/7/2003 9:48	0.9	6	260
1/7/2003 9:52	0.8	1	260
1/7/2003 9:56	0.9	14	260
1/7/2003 10:00	0.9	14	260
1/7/2003 10:04	0.8	10	260
1/7/2003 10:08	0.9	14	260
1/7/2003 10:12	1	10	260
1/7/2003 10:16	0.9	10	260
1/7/2003 10:20	0.9	6	260
1/7/2003 10:24	1	16	260
1/7/2003 10:28	0.9	6	260
1/7/2003 10:32	0.7	10	260
1/7/2003 10:36	0.9	10	260
1/7/2003 10:40	0.6	10	260
1/7/2003 10:44	0.7	10	260
1/7/2003 10:48	0.5	352	260
1/7/2003 10:52	0.8	349	260
1/7/2003 10:56	0.5	343	260
1/7/2003 11:00	0.8	350	260
1/7/2003 11:04	0.7	339	260
1/7/2003 11:08	0.7	331	260
1/7/2003 11:12	0.5	4	260
1/7/2003 11:16	0.9	6	260
1/7/2003 11:20	0.8	358	260
1/7/2003 11:24	0.7	355	260
1/7/2003 11:28	0.7	350	260
1/7/2003 11:32	0.8	1	260
1/7/2003 11:36	0.7	1	260
1/7/2003 11:40	0.8	357	260
1/7/2003 11:44	0.9	356	260
1/7/2003 11:48	0.9	359	260
1/7/2003 11:52	0.8	343	260
1/7/2003 11:56	0.7	1	260
1/7/2003 12:00	0.8	354	260
1/7/2003 12:04	0.7	356	260
1/7/2003 12:08	0.7	356	260
1/7/2003 12:12	0.8	358	260
1/7/2003 12:16	0.9	6	260
1/7/2003 12:20	0.7	356	260
1/7/2003 12:24	0.9	359	260
1/7/2003 12:28	0.8	357	260
1/7/2003 12:32	0.8	349	260
1/7/2003 12:36	0.8	357	260

1/7/2003 12:40	0.9	352	260
1/7/2003 12:44	0.9	6	260
1/7/2003 12:48	0.9	352	260
1/7/2003 12:52	0.8	1	260
1/7/2003 12:56	0.8	354	260
1/7/2003 13:00	0.8	353	260
1/7/2003 13:04	0.8	345	260
1/7/2003 13:08	0.8	2	260
1/7/2003 13:12	0.8	358	260
1/7/2003 13:16	0.7	6	260
1/7/2003 13:20	0.9	359	260
1/7/2003 13:24	0.7	356	260
1/7/2003 13:28	0.9	348	260
1/7/2003 13:32	0.9	355	260
1/7/2003 13:36	1.1	355	260
1/7/2003 13:40	1	357	260
1/7/2003 13:44	0.9	352	260
1/7/2003 13:48	1	346	260
1/7/2003 13:52	1.1	348	260
1/7/2003 13:56	1	357	260
1/7/2003 14:00	0.9	352	260
1/7/2003 14:04	1	349	260
1/7/2003 14:08	1	349	260
1/7/2003 14:12	1	342	260
1/7/2003 14:16	1	349	260
1/7/2003 14:20	0.9	345	260
1/7/2003 14:24	0.9	343	260
1/7/2003 14:28	0.8	342	260
1/7/2003 14:32	0.9	347	260
1/7/2003 14:36	0.9	335	260
1/7/2003 14:40	0.9	348	260
1/7/2003 14:44	0.9	343	260
1/7/2003 14:48	0.8	350	260
1/7/2003 14:52	0.9	348	260
1/7/2003 14:56	0.9	352	260
1/7/2003 15:00	0.8	349	260
1/7/2003 15:04	0.9	352	260
1/7/2003 15:08	0.9	356	260
1/7/2003 15:12	0.9	348	260
1/7/2003 15:16	0.8	350	260
1/7/2003 15:20	0.8	353	260
1/7/2003 15:24	0.8	358	260
1/7/2003 15:28	0.9	359	260
1/7/2003 15:32	0.9	355	260
1/7/2003 15:36	0.9	359	260
1/7/2003 15:40	0.8	349	260
1/7/2003 15:44	0.8	358	260
1/7/2003 15:48	2.1	323	260
1/7/2003 15:52	37.3	180	306
1/7/2003 15:56	2.6	304	337
1/7/2003 16:00	0.8	49	169

1/7/2003 16:04	2.1	19	230
1/7/2003 16:08	5.4	290	233
1/7/2003 16:12	6.4	286	242
1/7/2003 16:16	6.6	339	302
1/7/2003 16:20	5.6	323	293
1/7/2003 16:24	11.1	334	329
1/7/2003 16:28	4.4	343	319
1/7/2003 16:32	4.1	333	295
1/7/2003 16:36	2.8	305	264
1/7/2003 16:40	2.9	183	340
1/7/2003 16:44	0.8	116	157
1/7/2003 16:48	0.6	44	22
1/7/2003 16:52	1.1	184	295
1/7/2003 16:56	1.7	173	296
1/7/2003 17:00	1.8	196	296
1/7/2003 17:04	2.3	221	296
1/7/2003 17:08	3.5	232	296
1/7/2003 17:12	6.1	247	296
1/7/2003 17:16	6.3	249	296
1/7/2003 17:20	6.6	248	296
1/7/2003 17:24	6.9	249	296
1/7/2003 17:28	5.9	244	296
1/7/2003 17:32	5	242	296
1/7/2003 17:36	4.2	237	296
1/7/2003 17:40	4.6	233	298

## Flume Deployment

### Bishops Point - Pearl Harbor, Hawaii

Determination of Resuspended Solids Concentrations - Dry weight determination by filtration on Whatman low-metal TCLP filters (0.7  $\mu\text{m}$  nominal pore size) to constant weight of 1 mg. Volume of suspension sample was determined gravimetrically.

TSS									
Sample	Filter tare (g)	Filter-sed. Wt. (g)	Sed. Wt. (mg)	Bottle tare (g)	Bottle Wt. (g)	Vol. (L)	Con. (mg/L)	Sample Order	Shear Stress (Pa)
black	0.455	0.4671	12.1	234.8	694.8	0.46	26	1	
purple	0.4526	0.4859	33.3	235.8	691.3	0.4555	73	2	0.15
red	0.4574	0.4852	27.8	232.4	420.4	0.188	148	3	0.25
orange	0.4521	0.5089	56.8	238.7	686.2	0.4475	127	4	0.34
yellow	0.455	0.5419	86.9	239.7	677.5	0.4378	198	5	0.34
green	0.4508	0.6669	216.1	238.1	684.2	0.4461	484	6	0.46
blue	0.4586	0.8074	348.8	239.5	685.2	0.4457	783	7	0.62
white	0.4589	2.333	1874.1	238	691.9	0.4539	4129	8	0.85

## Flume Deployment

### Southeast Loch - Pearl Harbor, Hawaii

Determination of Resuspended Solids Concentrations - Dry weight determination by filtration on Whatman low-metal TCLP filters (0.7  $\mu\text{m}$  nominal pore size) to constant weights of 1 mg. Volume of suspension sample was determined gravimetrically.

Sample	Filter tare (g)	Filter-sed. Wt. (g)	Sed. Wt. (mg)	Bottle tare (g)	Bottle Wt. (g)	Vol. (L)	Con. (mg/L)	Sample Order	Shear Stress (Pa)
black	0.4633	0.7419	278.6	236.2	700	0.4638	601	1	
purple	0.4567	0.6966	239.9	226.6	694.7	0.4681	512	2	
red	0.4507	0.5989	148.2	226	503	0.277	535	3	0.11
orange	0.4742	0.5421	67.9	238.6	682.7	0.4441	153	4	0.16
yellow	0.4664	0.6993	232.9	226.6	491.8	0.2652	878	5	0.21
green	0.4534	0.4728	19.4	226.4	571.9	0.3455	56	6	0.29
blue	0.4549	0.7384	283.5	239.1	514.4	0.2753	1030	7	0.41
white	0.4605	0.4725	12	239.6	592.8	0.3532	34	8	0.41